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Foreword

The papers contained in this RECORD focus on the Wisconsin Department of Transportation approach to the Integrated Operation System, the goal of which is to improve the general levels of management within the Department and to develop the decision-making capability at the appropriate management level.

In the first paper, Bakke outlines the reasons for the establishment of new operation approaches in the administration of the department and sets forth 16 program goals for IOS operation.

Stephenson describes the concepts of the program budget system, which includes goal formulation, program definition, selection of program objectives, long-range program planning, management of operation, cost and responsibility control, and appraisal of results. The financial operating system, according to Stephenson, provides the working unit with the two types of data needed: resources and time.

Kerttula generally describes the planning element of the IOS program and states that this process includes the development and establishment of a set of goals, the selection and approval of a set of improvement projects, and the investigation and design activities required to realize the goals. This process leads to the actual highway improvement activities of land acquisition or site construction or both.

T. J. Hart defines the highway network data and information system as one designed to interface with project development and the program budget system. According to Hart, HNDI provides the capability to efficiently collect, process, store, and display highway-related data and information for all public works in the state.

Bacon discusses the integration of the computer with the management decision-making process to effectively implement the IOS program. Bacon outlines the various computer systems being used in Wisconsin.

This RECORD will be of interest to transportation administrators and managers at all levels of government as many innovative management ideas and concepts are presented in these papers.

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Integrated Operations System and Its Philosophy

G. H. BAKKE, Wisconsin Department of Transportation

The modernization of any large corporate structure has many mechanical and technical problems, but the human element is one of the most crucial problem areas. Therefore, a modernization process demands that management update its philosophy as well as its physical procedures to make employees receptive to major changes. The restructuring of the physical processes for the state's transportation needs was based on a decision that the most efficient system is one that integrates all modes of transportation: land, water, and air. To effectively implement such a system, management must take great care to ensure that employees and citizens understand that, despite temporary disruptions, the long-range program will operate more efficiently and conserve more of the taxpayers' resources. To this end, we have formulated 16 principles to aid in reducing the major stumbling blocks of both the physical and psychological innovations. They are designed to assure not only management but all employees and citizens that they will not be lost in a bureaucratic shuffle.

•OUR NATION has undergone rapid technological changes, accompanied by the development of a vast transportation network. As we recognize the complexities of our transport system, we are forced to develop new public policies for transportation and to use more sophisticated methods of analysis to solve problems. If we are to control the transportation system and to better its reputation with the public, our task is clear: Find ways to move more people and more material of lower value more miles at less cost. As government leaders, we must play a major role in promoting this effort. This is a brief, but large and demanding, order.

Our hands are not completely free to act, however. The proliferation of state services as well as the complexity of problems faced has outstripped many of our old problem-solving techniques. Because of this, organized government is under attack. We are experiencing dissatisfaction, suspicion, and rebellion, because we who represent government often do not measure up to the demands of the time. We witness unfulfilled promises, the proliferation and overlapping of agencies, illogical responses, and just plain incompetency.

Meanwhile, government continues to grow; the problems we face intensify; the daily work load increases. To modernize our governmental machine, we must resolve these problems. We have already begun the necessary reorganization of the physical structure, but that is not enough. We have to include the human element and provide for the growth of the individual employee.

As leaders we must help create a sense of rejuvenation in government. We have the opportunity to lead in the establishment of a philosophy for management with purpose, pride, and sense of belonging and fulfillment. In short, we must do our best to make government work and, moreover, make government make sense to the governed.

Many of the problems of government are a result of the unprecedented growth of new programs and the complexities of administering them. These problems are multiplied by the lack of qualified managers and intensified diligence in administration. Administration, it seems, totally loses the personal touch with the taxpayer.

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The transportation industry is especially characterized by its rapid growth (an annual rate of 10 percent). As the arterial system of our world, it is the communications link connecting commerce, agriculture, and industry. A smooth-running transportation network provides for our comfort and is one of the tremendous advantages of modern living. Therefore, we are dealing with needs borne of both desire and economic necessity.

As the second largest fiscal activity in our state, transportation has a budget of over $300,000,000 and more than 4,000 employees. Moreover, it is the state's most obvious service in the public eye. Our responsibility, therefore, is to provide a major public service. It is imperative that we understand our tasks, work together, and lead the way to improved and responsive government.

THE INTEGRATED STRUCTURE OF THE WISCONSIN DEPARTMENT OF TRANSPORTATION

In the past decade, the emphasis of transportation was on highways and highway travel. Now highways are only one part of a new and larger system that includes roadways, vehicles, and driver activities as controlled by environmental, legal, and situational factors. In turn, this concept is a division of the entire transportation system concerned with the total movement of people and goods, whether it be by air, water, or land.

Therefore, a segmented transportation policy will not work today. Each transportation mode must be treated with regard to the total transport system. One just cannot plan and construct highway, air, rail, or water facilities without considering the overall regulatory climate or integrating private investment, economic growth, social changes, and environmental factors.

As a result of a citizen's study committee, Wisconsin passed a general reorganization act in 1967, which combined three previously existing agencies into the new Wisconsin Department of Transportation: (a) the State Highway Commission, headed by three full-time administrators; (b) the Motor Vehicle Department, headed by an appointed director; and (c) the Aeronautics Department, headed by a full-time director and a part-time commission. This new organization was activated in August 1967.

The statutory powers and duties of the Highway Commission and the Division of Motor Vehicles were retained by those divisions, but they were subject to five functions assigned to the Office of the Secretary of the Department of Transportation: program coordination, budgeting, planning for all modes, controlling the internal organization, and related management responsibilities. The entire Aeronautics Division is controlled directly by the Office of the Secretary. The planning function includes active participation in federal regulatory cases before the ICC and the CAB.

With the governor's approval, the Division of Business Management was created. A steering committee lead self-analytical studies to determine what administrative services should be retained by each division and what services could best be performed on a department-wide basis. This resulted in establishment of four department-wide service bureaus in the Division of Business Management: Systems and Data Processing, Personnel, Management Services, and Management Analysis. A Division of Planning was also created and staffed by those individuals who understood the planning capabilities that had accumulated over the past decade in the Division of Highways.

Regardless of the organizational structure, the need still exists to arrange and integrate all these activities in order to operate with the most responsible problem-solving tools.

There are common-sense goals in restructuring the entire administrative system. One is to provide management with timely, reliable, and useful information that will keep decision-making at the lowest possible organizational level. By establishing a firm basis for planning more efficient systems in the future, one avoids the critical situation of outgrowing the capabilities of the present system. We must imperatively update our organization as necessary.

There are other fundamental reasons why we need to review and improve our operations, including the following:

1. Increased operating efficiency with the proper tools will make it possible to handle greater work loads without proportionate increases in staff.
2. Employees and the transportation industry must gain proficiency in the new, coordinated areas to effectively control the growing complexity of problems.
3. Such improvements will make government as understandable and responsive to citizens as possible.

To produce these results, we have implemented a new systems approach.

During the past few years, there has been great interest on the part of governmental agencies in the systems approach to the solution of problems and the implementation of planning and budgetary analysis techniques.

The Wisconsin Department of Transportation is proud to be a front-runner in applying this systems approach to government decision-making. To achieve this status, we identified our principal decision-making activities. We then arranged them in a logical, systematic manner. We call this effort our Integrated Operations System (IOS). The objective of the system is very basic: to improve the general levels of management within the department and the decision-making capability of our managers. This operation has three major management tools to assist the department in coordinating its tasks:

1. The Project Development System, which analyzes the technical information required to run a complete transportation program, i.e., the administrative rules and effective manufacturing methods.
2. The Planning System, which analyzes the social and economic information required to direct the transportation program in serving the needs of the state; this controls the operational rules and cost consequences of existing and proposed actions.
3. The Program Budget System, which analyzes the production information required to evaluate our department's ability in financially realizing the transportation program; it obtains and presents information pertaining to departmental operations.

Although these management tools are by themselves relatively simple, they do require a major change in management philosophy for orderly and effective implementation.

The recognition of the need for a fundamental change in management outlook in order to use these tools has led the Wisconsin Department of Transportation to emphasize the basic and establish new and imaginative management principles and policies. They are the key to the effective human understanding and physical establishment of an Integrated Operations System.

We have devoted over half of these principles and policies to help put the personal back into personnel. We know that without the support of the men and women who perform even the most basic of tasks, a sophisticated operation such as ours could never be an effective and efficient tool. Achievement is the goal. Organizational structure cannot be an end of itself; a team effort is the means. It is to promote this understanding and to clearly define our goals that we have set down these guidelines.

THE SIXTEEN PRINCIPLES

Continually Evaluate the Transportation Needs of the State and Recommend Changes to Satisfy These Demands

Needs rapidly change with the times; so to keep pace the department must plan ahead. What is adequate service today will not suffice tomorrow. Our services will be constantly updated to ensure that they are functioning in an efficient, effective manner.

Assign Priorities

The allocation of resources must be placed in a logical sequence. Priorities are being assigned to all areas to make certain that the taxpayer and the department get the most service for their money and time.

Create a Flexible Organization Structure

No two organizations are alike. To provide for management and employee flexibility, the organization must also be flexible. The level of individual effort will be increased if the employee knows that constructive answers exist to his problems.

Reduce the Cost of Established Services Through Better Work Methods, New Techniques, and Increased Production

The cost of established services must be reduced in order for the department to fulfill new program responsibilities. New demands and new priorities are established each year to maintain a high degree of efficiency and to ensure the best use of resources.

Operate on a Decentralized Basis

This will give the lowest level decision-maker the authority required to carry out his assigned responsibilities. This decentralization is also necessary because the department has unique responsibilities all over the state.

Inspire Department Managers to Continually Develop and Practice Self-Improvement

The implementation of major system changes can only be done with the support of all levels of management. Therefore, we have emphasized that managers should constructively criticize their operations and assist in the development of new improvements. A highly qualified staff will be made available to assist these managers with the implementation of major "self-improvement" programs.

Emphasize Flexibility and Alternation Among Management Personnel

To assume broader responsibilities, managers should be exposed to areas other than those for which they are directly responsible. When managers have a more comprehensive view of an entire operation, they are capable of facilitating their own tasks and understanding the problems of others. This should lend to increased teamwork and smoother production.

Give All Personnel Responsibility for Recommending Improvements

All employees will continue to make important recommendations for changes. We must create an atmosphere where these recommendations can be thoroughly and quickly evaluated. Sound suggestions must be acted on so implementation is speeded up.

Improve All Lines of Communication by Improving Formal Reporting

Reporting will be improved and extended by establishing formal reports only where needed. This formal reporting system will eliminate certain subordinate management levels. The communications role now played by these levels will be automatically provided by the new, improved reporting system. We also believe that a flat organization structure (that is, a limited number of subordinate supervisors) will provide for greater flexibility and effective response to changes.

Operate as Much as Possible as a Private Business

Employees will be rewarded to the greatest extent possible on the basis of their contribution to the entire department, not just on their personal goals and objectives, or those of their sections and division.

Establish an Atmosphere That Will Promote Positive Attitudes on the Part of All Employees

We must eliminate negativism by making an effort to say yes rather than no. New ideas and programs will never be tested if people cling only to the old way. Remember that every old way was once a new way. A positive response may mean more work at first, but if a new program works, in the long run it should lessen the time and burdens of the task.

Provide Growth Opportunities for All Employees Through Training and Retraining

Staff requirements change with techniques and result in a greater emphasis on technical and professional work. All employees must be provided with the opportunities to upgrade themselves into these new and more challenging positions.

Have Managers Establish Goals for Each Employee and Each Function

These goals will help the employee to understand how he fits into the overall organization. The result should be improved individual motivation and continuing improvement and efficiency in the tasks being performed.

Establish New Standards of Performance for Employees

These new standards will increase motivation and morale by providing a measurement of the efficiency of the employee and by letting him know specifically what is expected in the task being performed.

Make Use of New Management Tools

Our new management tools include electronic data processing equipment, operations research techniques, work measurement techniques, and various types of engineering and law enforcement equipment.

Develop Guidelines and Standard Procedures for All Repetitive Functions to Ensure a Consistent Quality and Measurable Output of Work

The reporting of errors and exceptions through standard repeated actions is more timely and meaningful to management. In developing or controlling a system, the easiest way for managers to identify problem areas is through spotting exceptions to standard procedures. They are easy to detect and quickly understood.

It is our aim to fully implement these 16 fundamental management principles to ensure that the Department of Transportation remains young and innovative, a good place to work, and is fully responsive to the needs of the citizens of Wisconsin.

Program Budget and Financial Operating Systems

T. E. STEPHENSON, JR., Wisconsin Department of Transportation

The concepts of the program budget system (PBS) include goal formulation, program definition, selection of program objectives, long-range program planning, management of operation, cost and responsibility control, and appraisal of results. In a broad sense, PBS is closely associated with every phase of planning and ties the various subsystems together. Instrumental to an effective PBS is a systematic approach to decision-making. PBS is structured to provide the total picture of the resources required, available, and used, and to determine how well the resources available are planned and, after the fact, how they were used. It is also involved in conducting current operations and in the appraisal of those results. PBS determines the way in which scarce resources are allocated among competing needs and how effectively these resources are used.

The data requirements of PBS are merged with the fiscal accounting, personnel, and payroll needs to provide the basic source of financial and budget information for the entire department. Thus, the financial operating system becomes the integrated accounting system for management. In performing these business functions, the financial operating system provides the working unit with the two types of data needed: resources (men, money, and materials) and time (process and/or production values). These data are most effectively supplied from the integrated accounting system obtained through the use of electronic data processing.

•THE PROGRAM BUDGET SYSTEM (PBS) and the financial operating system (FOS) were designed as integrated subsystems of the larger Integrated Operations System (IOS). PBS is a procedural component and FOS is a computer-based component of IOS. Together, these subsystems obtain and present information pertaining to department operations. PBS provides the methodology to analyze the production information required to evaluate the department's ability to financially implement the transportation program. FOS provides the accounting function that serves as the financial link between headquarters and the operating divisions.

PBS and FOS are concerned with department operations, a subject too comprehensive and too complex to describe briefly. The budgetary decision process is the least understood component of PBS. This report will emphasize this process and its relationship to planning, IOS, and FOS.

Let us closely examine the actual decision-making process and follow this decision-making process through PBS to its place in the IOS.

PROGRAM BUDGET SYSTEM

What Is Program Budgeting?

Program budgeting is a method, or structured procedure, formulated to assist management in making better decisions on the allocation of resources. The necessary decisions on resource allocations require that the emphasis be on planning and management rather than on fiscal control. The resulting budget document serves as a

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communications device within the organization for linking strategic planning, management control, and operational control.

As defined, program budgeting is a systematic method of considering a multitude of facets, alternatives, and constraints to assist management in organizing ambiguous goals into actual resources. But, there is a large gap between the goals of society and the resources available to realize these goals. Program budgeting attempts to establish priorities to bridge this gap. Goal and resource activities are classified, organized, and analyzed into groups called programs. The given resources for each activity assess the programs, which in turn lead to priorities that establish practical objectives. This gives a statement of the currently attainable social goals.

This program development process is especially adaptable to a traditional transportation organization. Using this structure, we can easily relate several activities to traditional functions (such as improvement, maintenance, and enforcement) through a mode or operation (e.g., highway or regulation) to the end results of mobility, safety, beautification, and utility.

Inferred Applications of Program Budgeting

The main purpose of program budgeting is to relate specific resources to specific results. Better decision-making capabilities should result if this procedure is carried to all activities within such a program development process or structure. The effectiveness of the resource allocation decision is directly proportional to the level of direction provided to those doing the resource estimation. This direction must be provided by management in terms of strategic objectives, priorities, and assignment of responsibilities.

Program budgeting is a formalized approach to decision-making using a budgetary document as its principal tool for understanding production. Again, this is used to serve the organization in strategic planning, management control, and operational control.

This method demands a fundamental change in language as well as in the work classifying and organizing schemes of the department. All managers and users of this system must have a common language, dictated by policy, in order to effectively communicate. If this requirement is ignored, any attempt to implement program budgeting could be an exercise in clerical futility.

A SYSTEMATIC METHOD OF DECISION-MAKING

The procedures, products, and language of program budgeting must be emphasized throughout the department until they automatically become the traditional methods of planning, organizing, and communicating.

Let us closely examine the actual decision-making process. What exactly is this planning and budgeting method that uses a systematic approach to decision-making?

Classifying the Activities

In our case, the first step is to arrange the transportation activities that must be administered into logical groups for decision-making. There are two decision-making opportunities for each activity: (a) the operating objectives, or What do we want to accomplish? and (b) resource allocation, or What are we going to pay for them?

To facilitate matters, we have classified our activities into 122 kinds that we call projects. As an aid to the user, these projects have been grouped into 27 types within eight categories. This makes it easier to adjust the overall program to the established legislative directives. The user is provided with standard guidelines called project descriptions that help him classify and prepare his short- and long-range work. Figure 1 shows the structuring of activities into the projects, types, and categories.

Selecting the Types of Decisions

Any systematic approach to decision-making requires classification, so our next major step is to identify the types of decisions to be made. Our approach emphasizes

Department Administration

- Administration Projects
  - General Administration
  - Meetings and Conventions
  - Training
  - Required Administration
- Transportation Administrative Services Projects
  - Management Analysis Services
  - Systems and Data Processing Services
  - Management Services
  - Personnel Services
  - Required Administrative Services
- Highway Administrative Services Projects
  - Highway Office Services
  - Public Information Services
  - Engineering Services
  - Budgeting (PBS) and Accounting Services
  - Required Administrative Services

Service Centers

- Transportation Rate Service Centers
  - Vehicle Service Center
  - Computer Service Center
  - Engineering Supplies Service Center
- Highway Rate Service Centers
  - Reprographics Service Center
  - Engineering Services Service Center
  - Materials Testing Service Center
  - Sign Manufacturing Service Center
- Services and Materials Sold to Other Governmental Units Projects
  - Professional Technical Services for Others
  - Sales of Materials to Other Governmental Units

Support Services

- Planning Projects
  - Special Studies
  - Policy Planning
  - Traffic Planning
  - Legal Coordination
  - Urban Transportation Study
  - State Planning
  - Road Inventory
  - Highway Improvement Planning
- Research and Development Projects
  - Highway District Research
  - Bureau Research
  - Planning Division Research
  - HNDI Development
  - Engineering Bureau Research
  - Unclassified Highway Research
  - Computer Services Research
  - Nonhighway Research
  - Required Research
- Physical Plant Management
  - Capital Land and Buildings
  - Permanent Property (Equipment)
  - Buildings and Grounds
- Miscellaneous Services Projects
  - Litigation
  - Property Management
  - Construction of Equipment
  - Unclassified Miscellaneous Services

Highway Aids and Accounting Services

- Highway Aids Projects
  - Basic Aids
  - Supplemental Aids
  - Privileged Supplemental Aids
- Legislative and Accounting Services Projects
  - Topographic Maps
  - Hydrologic and Hydraulic Surveys
  - Fire Protection Reimbursement to Local Government
  - Legislative Awards
  - STH Allotment County Bonds
  - Cancelled Drafts
  - Claims Commission Awards
  - Safety Coordination by the Governor
  - Lease Rental (Bonding) Payments
  - Attorney General Services
  - Railroad Grade Crossing Protection
- Accounting and Budgetary Projects
  - Revenue
  - Budget
  - Accounting

Highway Maintenance

- Maintenance Projects
  - General Maintenance
  - Winter Maintenance
  - Winter Maintenance State-Furnished Materials
  - Unclassified Maintenance
  - General and Special State-Furnished Materials
- Traffic Maintenance Projects
  - Pavement Marking
  - Sign Erection and Replacement
  - Electrical Maintenance
- Special Maintenance Projects
  - Special Roadway Maintenance
  - Special On-System Bridge Maintenance
  - Special Off-System Bridge Maintenance
  - Special Emergency or Miscellaneous Maintenance
  - Special Roadside Maintenance
  - Special Roadside Improvement Performed Under Maintenance

Improvement Project Program

- Improvement Project Budgets
  - Design Process
  - Structure Planning
  - Acquisition Planning
  - Construction Planning
  - Structure Design
  - Special Design
  - Right-of-Way Acquisition
  - Utility
  - Construction

Improvement Level of Effort

- Design Investigation (DI) Projects
  - Design Investigation Annual Level of Effort
  - Costing Project for DI
  - Special DI Project
- Improvement Resurfacing Projects
  - Resurfacing Annual Level of Effort
  - Planned Resurfacing
  - Costing Resurfacing
- Improvement Marking and Signing Projects
  - Markings and Signing Annual Level of Effort
  - Marking and Signing On-System
  - Marking and Signing FAS Off-System

Specific Highway Improvement Programs

- Railroad Projects
  - Railroads Annual Level of Effort
  - Railroad Engineering
  - Railroad Construction
- Park, Forest, and Public Access Road Projects
  - Park, Forest, and Public Access Roads Annual Level of Effort
  - Design Project for Park, Forest, and Public Access Roads
  - Construction Project for Park, Forest, and Public Access Roads
- Institution Roads Projects
  - Institution Roads Annual Level of Effort
  - Institution Plans and Surveys
  - Institution Construction
- Roadside Improvement Projects
  - Roadside Improvement Annual Level of Effort
  - Design Roadside
  - Construction Roadside
- Scenic Easement Projects
  - Scenic Easements Annual Level of Effort
  - Easement Platting
  - Easement Acquisition
- Projects for Traffic Operation Projects to Improve Capacity and Safety (TOPICS)
  - TOPICS Annual Level of Effort
  - TOPICS Investigation
  - TOPICS Support Services
  - TOPICS Design
  - TOPICS Construction
- Federal Secondary (FAS) Off-System Projects
  - FAS Off-System Annual Level of Effort
  - FAS Plans and Surveys
  - FAS Construction
  - Long-Duration FAS Off-System Project Budgets

Figure 1. Structuring of activities into projects, types, and categories.

budgetary control, a key to efficient administration in any enterprise, especially a large, complex one. Therefore, we have defined three types that cover all possibilities (Fig. 2):

1. Annual objectives and value comparisons,
2. Annual level of effort and priorities, and
3. Continuing project budget approval.

Annual objectives and value comparisons are applied to similar activities grouped by organization. It is a commitment to do specific work. The resources must be compared and balanced with objectives or planned accomplishments so management can determine relative priorities. This requires a four-step process to obtain the implied budget: (a) administrative direction before estimating resources and accomplishments, (b) self-analysis to ensure that estimates comply with the administrative directions, (c) independent analysis for establishing the desired compliance and resultant effect,

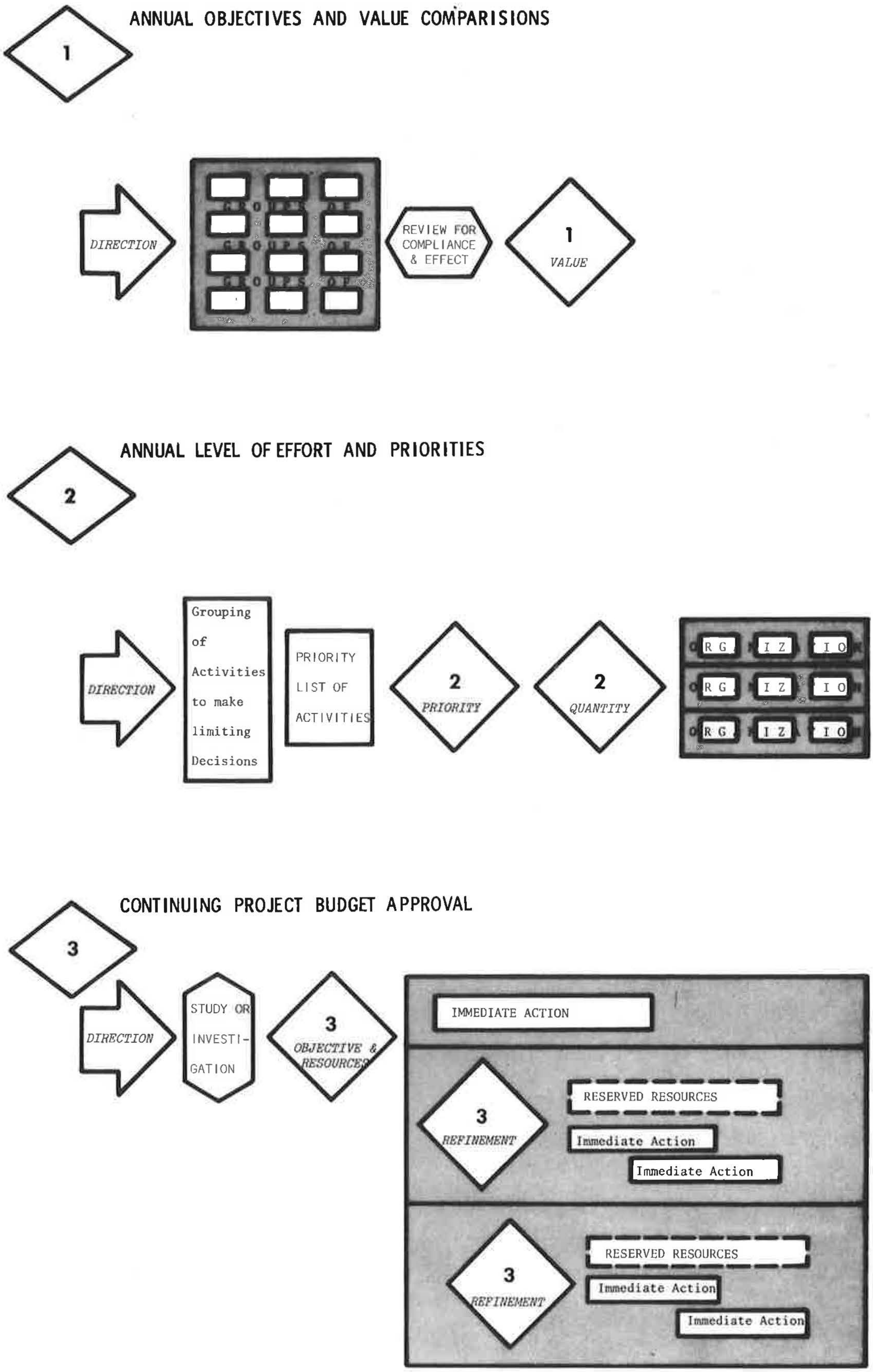


Figure 2. The three types of decision-making.

and (d) the decision for action. Typical activities for this type of decision-making are those of an administrative or support service nature.

Annual level of effort and priorities consist of grouping activities to satisfy management's need to make limiting decisions. It consists of an implied commitment for a category of work in priority order. This kind of decision requires a five-step process: (a) administrative direction by legislation or historical trends before estimating the resources and accomplishments, (b) list of planned accomplishments for priority activities before estimating the resources, (c) decision for action on the list of activities in priority order, (d) decisions for action on the quantity of the effort to be expended in a specified time period, and (e) specific activities to be started when conditions are met by the supervisor and when resources are available.

Thus, a continuing action is authorized with implied approval until the actual level of effort or listed accomplishments are reached. This type of decision is especially required where needs far exceed available resources. Therefore, priorities must be predetermined by management.

Typical of this activity is highway maintenance. Historical trends tell us that we must budget a certain level of effort (resources) for winter maintenance and highway damage claims. Roadside improvements, such as scenic overlooks and waysides, also fall into this category. In the area of support services, the electronic data processing systems and programming activities use this approach.

Continuing project budget approval is the result of a study or investigation. The decision required at the completion of this process must include approval of the objectives and resources for the entire operation, which covers a period of years. In other words, the decision that management makes requires the authorization of some immediate action, followed by implied authorization for future action to be financed by reserved resources. This process demands that management make day-to-day decisions of a refinement nature in order to activate the reserved resources.

Typical activities of this type are investigations normally done by management's own staff. The result is usually a report with recommendations for an action in terms of phases or stages for implementation. For example, management can say: "Phase 1 is approved; have it completed in 18 months." During phase 1, investigation recommendations are refined and proposed to management for authorizing action into phase 2 and possibly into phase 3. In this example, the first action (phase 1) requires two subsequent refinement decisions (phases 2 and 3) to accomplish the entire objective. This process is typical of that applied to highway investigation, design, land acquisition, and construction functions.

Applying the Types of Decisions

The continuing decisions are the most difficult because we make them today, and they may control our operations for the next 10 years. In fact, we are now operating under decisions of this type made 10 years ago. The key to simplifying this type is to realistically group the implied authorizations so that refinement decisions can be scheduled in advance. This way the reserved resources can be tapped on a scheduled basis without undue problems. Figure 3 shows the continuing decision-making process and how these decisions are summarized into an annual program.

Decision types 1 and 2 should be the easiest decision-making processes when approached systematically. Management can easily make these annual decisions if planned and scheduled well in advance. We should arrange as many of our operations as possible for these types of decisions. Figure 4 shows that nearly half of the programs for the Wisconsin Department of Transportation can be decided on annually.

Administrative emphasis must be on the continuing type of decision because of the large dollar value and time expended. This is Wisconsin's transportation improvement project program, which requires decisions each year on over 500 projects that are worth about $122 million. As explained, each project is the result of an investigation. Accordingly, the first priority must be managing the investigation process.

Investigations are created by the type 2 decision-making process, annual levels of effort and priorities. We establish priorities, then determine the required level of

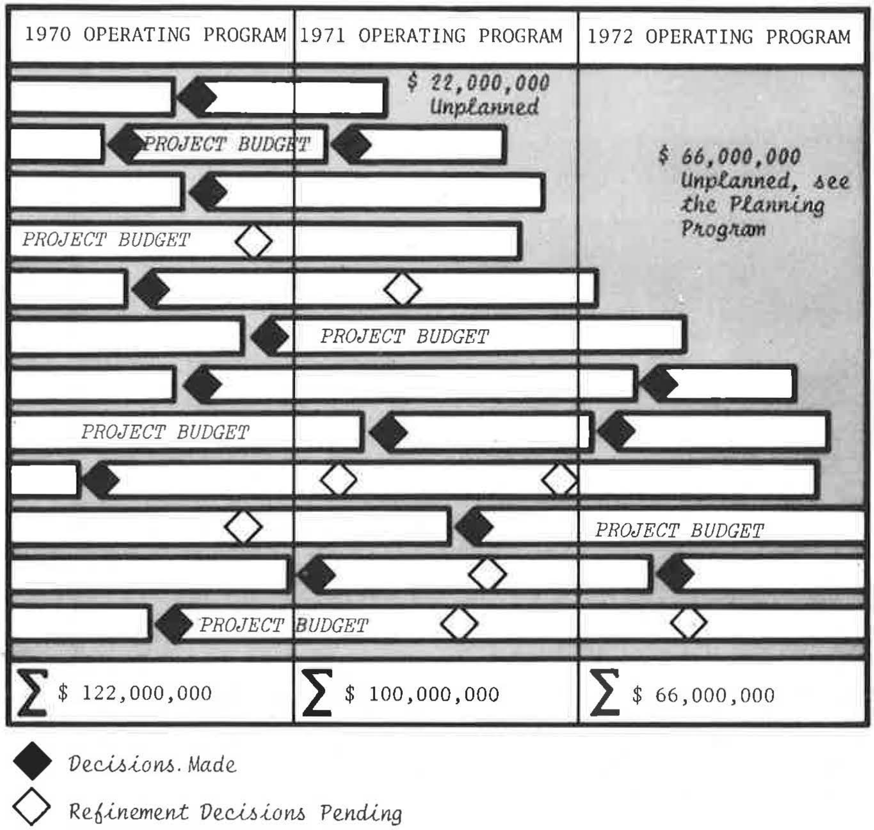


Figure 3. Continuing decision-making in annual programs.

effort so each organization may proceed with its work and investigation processes in a systematic manner. Therefore, management can schedule these decision opportunities far in advance. By knowing the relative priority assigned to each project, management can also predict the effects of each project on the overall program. The investigation team must also recommend the continuing action in terms of immediate action for design and reserved resources for right-of-way and construction. This leads to decision type 3, continuing project budget approval. We have arranged our activities into meaningful groups, defined the types of decisions that have to be made, and identified the type of decision needed for the groups of activities. What is the next step?

Defining the Budgetary Decision-Making Process

The third step in defining a systematic method of decision-making is to examine the overall procedure. There are four parts to this step: (a) obtain direction in terms of goals and objectives by the administrators, (b) estimate the resource requirements and accomplishments of the planned activities, (c) review the estimated resources and accomplishments for compliance and effect, and (d) obtain the authorization for action. In summary, we have defined a basic four-step process of direction, activity planning, review, and approval (Fig. 5).

Before any action can be taken, specific direction, review, and evaluation must be performed below the department level. The direction is usually provided within each control organization by the district engineer or bureau director. The program is again refined by the assigned project manager, who must establish the specific activity

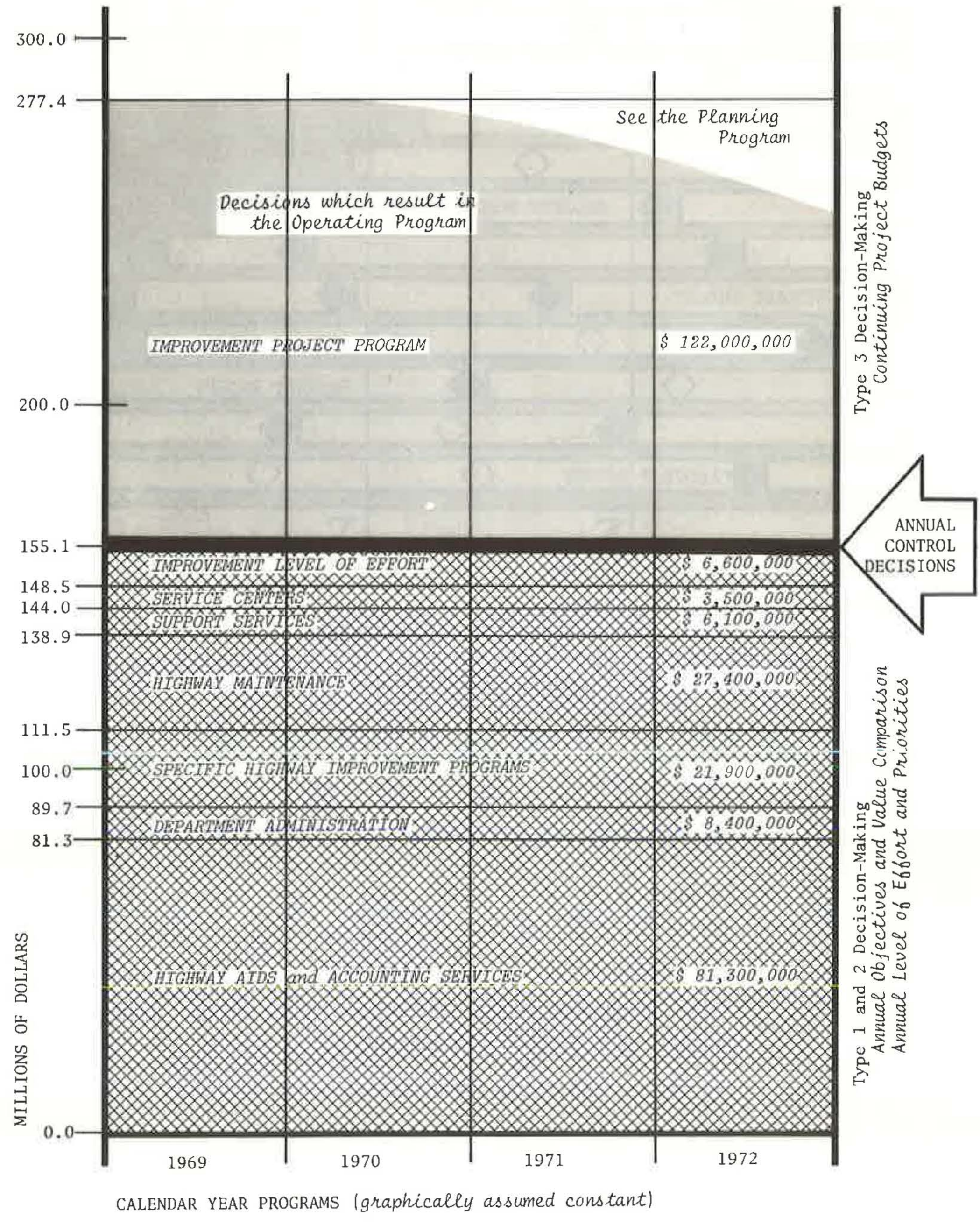


Figure 4. Transportation program and decision-making types.

objectives and estimate the resource requirements. The process, then, is department direction refined at the district or bureau level and again refined by the actual manager responsible for the project.

Review and analysis are essential. We normally get self-analysis by the project manager and again for leveling and balancing within the districts or bureaus that determine if they have the necessary resources for the activities. We also have a review by the department for each of the designated activities. This review is for effect as well as compliance. Finally, a staff organization provides an independent analysis to ensure management that all responsibilities conform to the department's original directions.

Defining Independent Analysis

What are the concepts for independent analysis? If we use the theoretical approach, there are three basic units: (a) production or budgetary analysis for operation control, which obtains and presents information pertaining to the department's internal performance and production capabilities; (b) technical or management analysis for management control, which determines the administrative rules and analyzes manufacturing methods for efficiency and effectiveness; and (c) economic or policy analysis for strategic planning, which determines the operational rules and cost consequences of existing and proposed actions.

These analyses and their resulting decisions are recorded in three management documents: the budget, administrative directives, and policy memoranda (Fig. 6). The administrative and policy documents result from continuing decisions. They are maintained in the Transportation Administrative Manual. The budget is a document prepared annually by organization or biennially by program. The budget includes management and planning decisions as well as operational decisions to ensure that the budget serves its communications purpose.

Completing the Process Definition

After we complete our reviews and analyses, we can make the decisions Thus, we can have a complete budget approval process as shown in Figure 7. This is a very simple process that must be understood by everyone involved.

A flow chart for the department describes the complete budget process by combining a chart for each of the 27 project types. In preparing this flow chart, we have asked the following questions about each group of activities:

1. Is the grouping meaningful?
2. What type of decision-making will be used?
3. Who is responsible in the department for this group?
4. Will there be department direction for the next year?
5. What kind of independent analysis will be performed on this group of activities?
6. Who represents the department in reviewing and making the decision?

Figure 8 shows a portion of a chart that resulted from using this budgetary decision process.

Some groups of activities need not have an independent analysis, whereas other groups of activities will not need departmental direction. Other groups of activities will not, for the moment, be assigned a department-wide responsibility. Thus, by using this systematic approach, management can understand and assign the appropriate degree and type of control necessary so that it is completely aware of where to apply administrative emphasis. As the decisions are made, through approvals or in terms of direction, they are recorded in the appropriate management documents and thereby communicated to the operating organizations.

Defining the Linkage Between Planning and Budgeting

When placed in operation, this decision-making process becomes complicated. It must be kept simple in order to be understood and used in the planning and budgeting areas. The first and last steps of this process—direction and resource allocation—should be reemphasized.

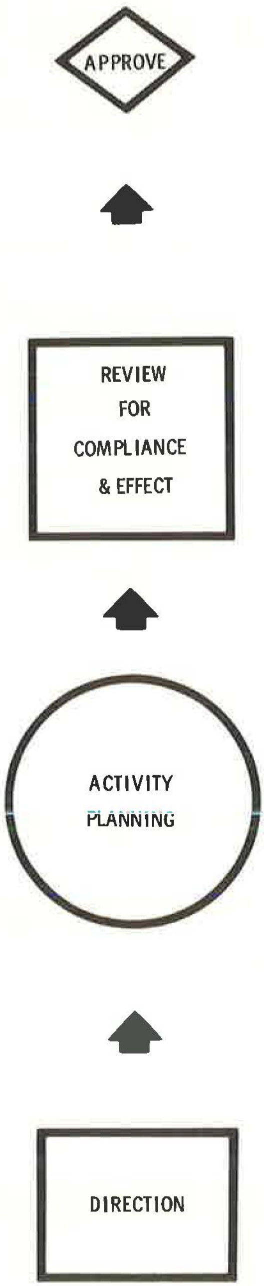


Figure 5. Basic four-step decision-making process.

Figure 6. Defining independent analysis.

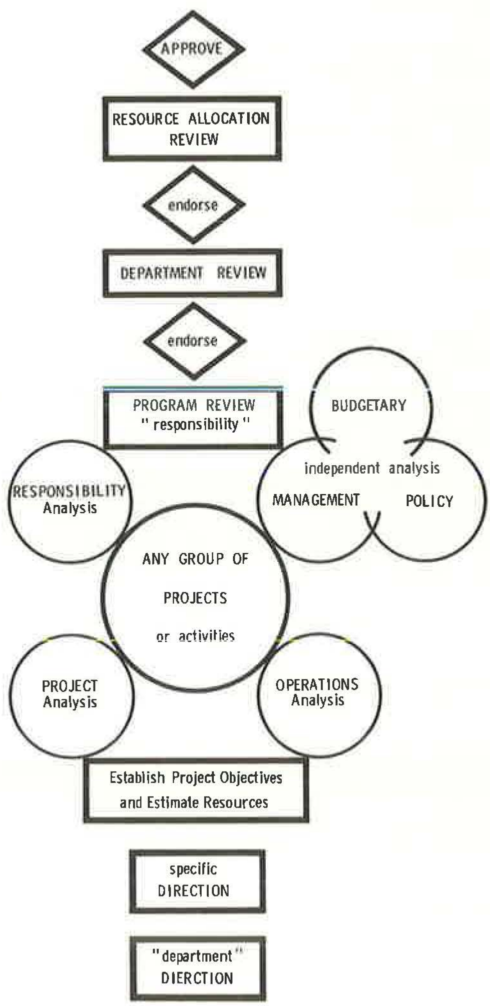


Figure 7. Complete budgetary decision process.

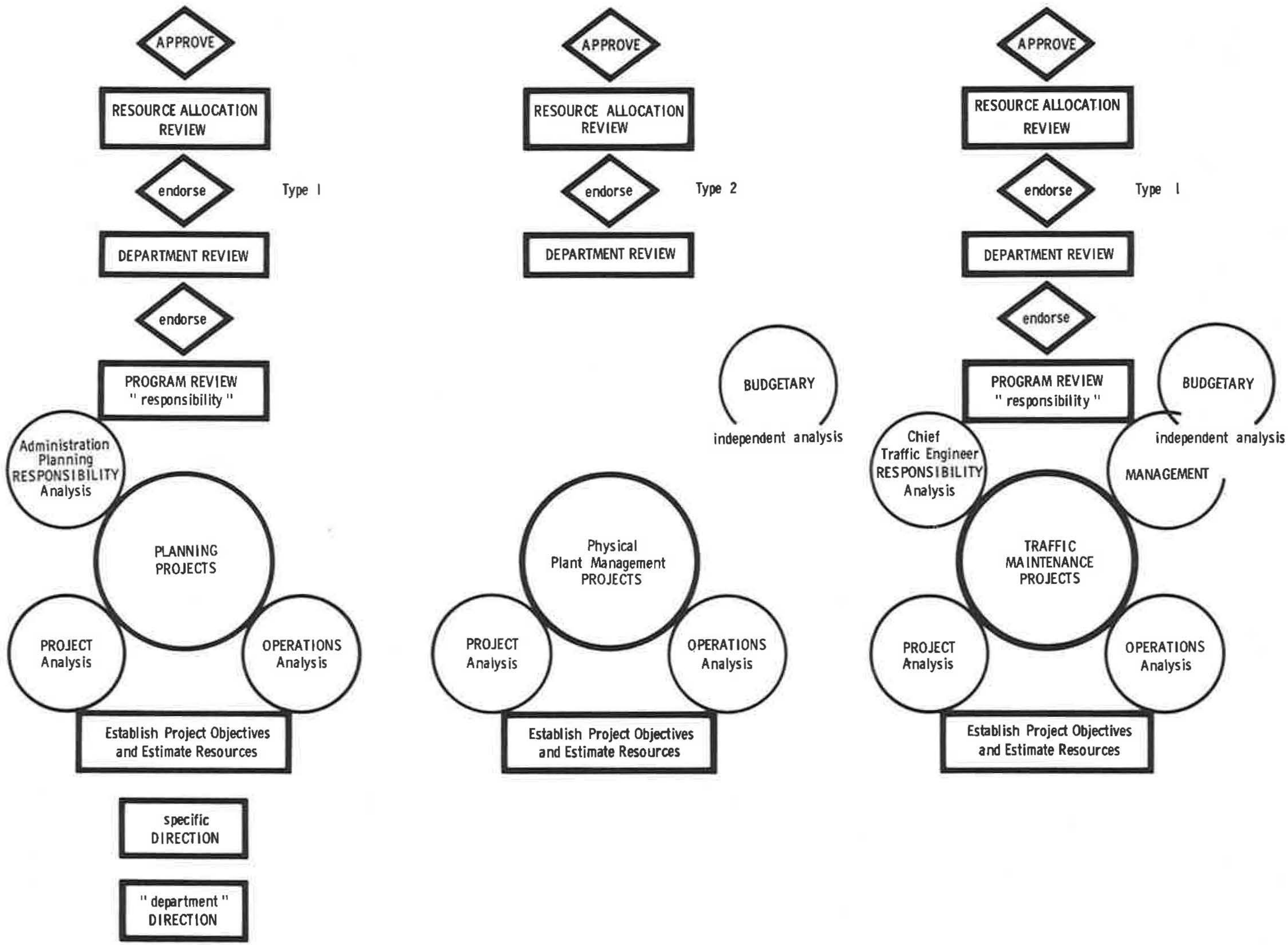


Figure 8. 1970 annual budget review.

The decision process starts with direction, which is strategic planning. This direction is a product of the formal planning process and results in policy statements for the department on the following:

1. Goals, resulting from the statewide physical planning process; and
2. Objectives, resulting from the level of service selection and the priority ranking processes.

The process ends with the following resource allocation decisions that are documented in the budget:

3. Program budgets, resulting from grouping of activities by function, and
4. Operating budgets, resulting from summarizing the various decisions by organization and responsibility.

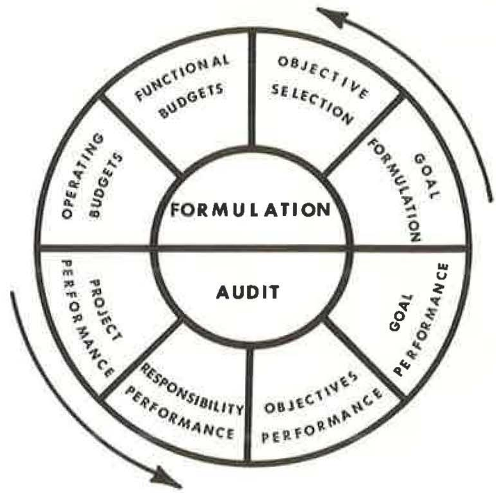


Figure 9. The cyclic process common to planning and budgeting.

As numbered, this becomes the structured sequence of events that link planning to budgeting. If we include the audit function traditionally associated with these events, the following structured cycle evolves:

1. Goal formulation and goal performance,
2. Objectives selection and objectives performance,
3. Functional (program) budgets and responsibility performance, and
4. Operating (project) budgets and project performance.

Because this is a cyclic process, we can graphically illustrate these steps as a wheel (Fig. 9).

Furthermore, because the data bases and analytical methods are different, there would be two wheels, one for planning and one for program budgeting. These wheels are graphically illustrated as gears to identify the required integration of procedures (Fig. 10).

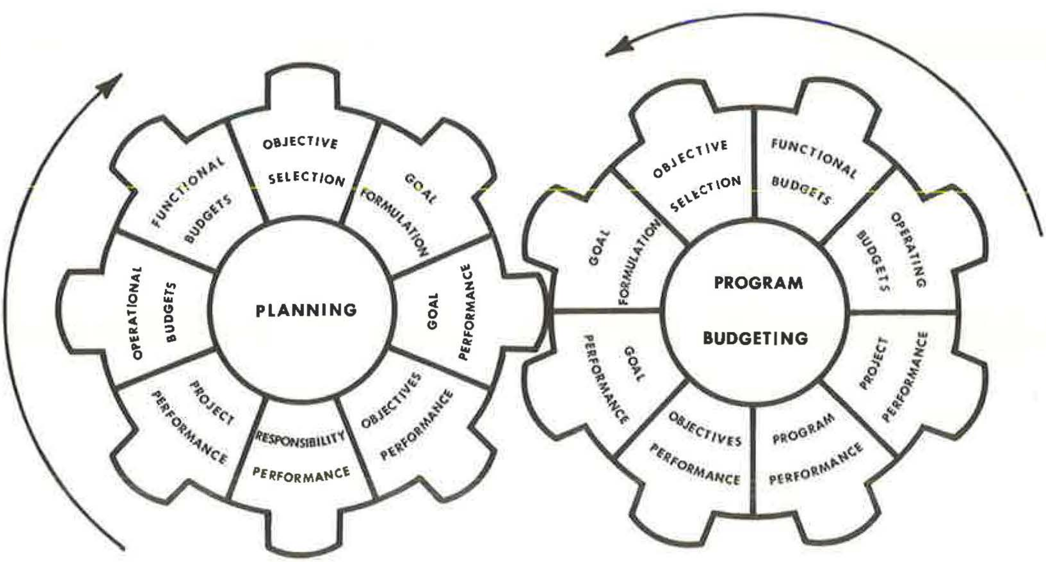


Figure 10. Integrated procedures for planning and budgeting.

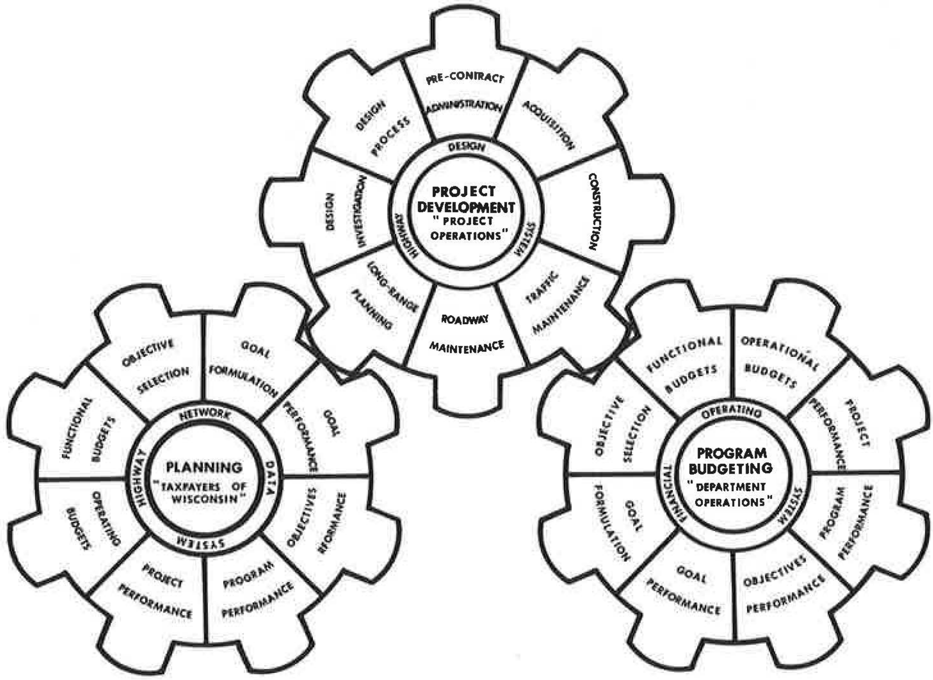


Figure 11. Integrated operations system (IOS).

The steps listed in the figure (goals, objectives, and functional and operating budgets) become the subsystems of both planning and program budgeting.

Defining the Data Bases

The data base for planning's economic analyses is the taxpayers of Wisconsin. Wisconsin's filing system for these data is the highway network data and information system.

The data base for production analyses by program budgeting is the dollar and manpower resources available to the Wisconsin Department of Transportation. This system depends on the sophisticated computer-based financial operating system (the integrated accounting system) for its data and information.

When these systems are linked to the project development system we can graphically illustrate all of IOS through a series of gears (Fig. 11).

In summary, PBS when linked to the "p" for planning includes most of the decision-making processes and generally controls goal formulation, program definition, selection of program objectives, long-range planning, management or operations, costs and responsibilities, and the appraisal of overall results.

Selecting the Common Information Link

Because planning and budgeting are integrated, they must have a common information link. Wisconsin has chosen the traditional highway programs as the common denominator between goals and operations. These categories of information are improvement, maintenance, aids, regulation, administration, and support services. Accordingly, planning and budgeting information on goals, objectives, and functional and operating budgets are summarized according to these categories called subprograms in Wisconsin's program structure.

Understanding the Different Audit Methods

The budget audit is easily understood. One simply compares the planned or budgeted resources with the expenditures. This fulfills the quantitative audit function.

Planning is more difficult to audit because it has no set resource values for its goals. The accepted cost/benefit methods use dollars as the common resource value. Cost/benefit methods assume dollars for a facility can be compared to a dollar value for safety or beauty to find a total cost. It assumes that all factors can be converted to dollars as a tool to assist decision-making, and that this tool serves as the base for auditing.

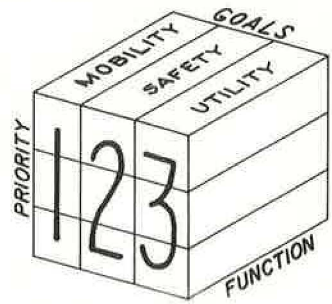


Figure 12. Three-dimensional goal-priority-function matrix.

We must have a plan and action before we can audit. In reality we review the action taken to implement the plan as our audit. The question now is: Shall we provide a plan for decision-making through cost/benefit methods, or is there another method that would be more effective to the planning decision-maker?

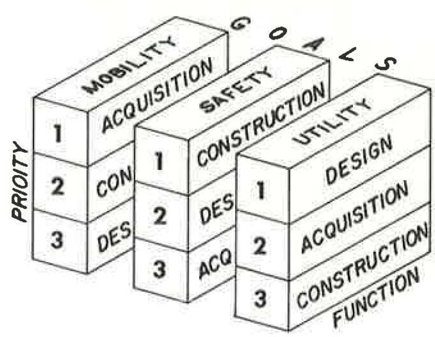


Figure 13. Value judgment of goal-priority-function matrix.

What we have to realize is that planning is based more on value judgments than on actual dollar values. We cannot place a dollar value on goals and objectives because we do not know quantitatively the cost of the effect. Because we are not dealing with a specific cost, what we are doing is making value judgments about what should be, not what is.

Value judgments do not come from off the top of the head, however. They are sometimes called "guesstimates". We look at the entire system and try to make an intelligent decision on what should be. To aid us, we can use a three-dimensional matrix. The three sides of this matrix are goals, functions, and priorities. Because there are various categories within each of the three, let us use goals and assign to it mobility, safety, and utility. Figure 12 shows the subdivision of the three-sided matrix. Now we are ready for the value judgment, the identification of priorities. Priority 1 is mobility, priority 2 is safety, and priority 3 is utility. Within each of the goal categories we must make another value judgment as to the function to be performed:

1. For mobility priority 1 is acquisition, priority 2 is construction, and priority 3 is design.
2. For safety priority 1 is construction, priority 2 is design, and priority 3 is acquisition.
3. For utility priority 1 is design, priority 2 is acquisition, and priority 3 is construction.

This is graphically shown in Figure 13.

In essence each of the priority lists prepared is lineal. The task now is the integration of these lists into a single matrix with the following priorities:

Priority 1 is mobility-acquisition
Priority 2 is safety-construction
Priority 3 is mobility-construction
Priority 4 is utility-design
Priority 5 is mobility-design

Priority 6 is safety-design
Priority 7 is safety-acquisition
Priority 8 is utility-acquisition
Priority 9 is utility-construction

Now our matrix is as shown in Figure 14.

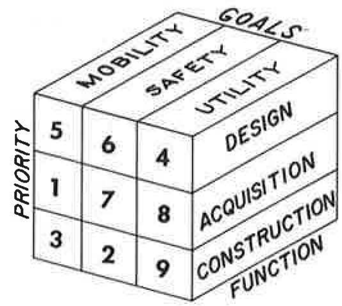


Figure 14. Matrix of the integration of judgment list.

How Is This Used?

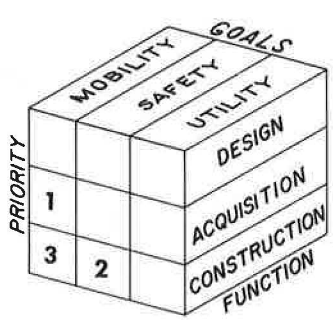
The task is to match the best combinations of categories within the structure. Assume that we have nine projects that need attention, and it would cost $5 million to implement them all. If we only have $2 million, some projects are going to be shelved.

Now comes the value-judgment listing by priority. Using the established decision-making matrix for planning, we can obtain the following priority and dollar list:

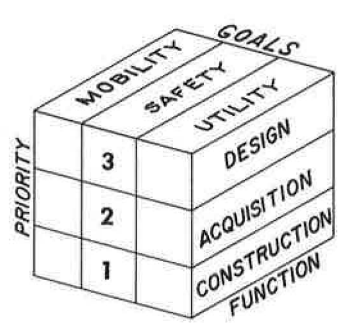
Priority	Cost	Management Selection
1	$1,000,000	
2	500,000	1
3	500,000	
4	250,000	
5	250,000	
6	500,000	2
7	1,000,000	3
8	500,000	
9	500,000	

The first three priorities equal the dollar control. But management elects to implement priorities 2, 6, and 7. Planning now must analyze the effects of management judgment. This is called planning's audit (Fig. 15).

Based on the decisions made when compared to the established matrix, planning could report on the performance of the decisions. Planning could prepare an annual audit report highlighting the areas of compliance and noncompliance and their relative effect on the taxpayers and the department. A second decision matrix could be prepared for objectives that would analyze for Wisconsin priorities between the several modes of transportation. A third matrix utilizing the common data base, namely the traditional transportation programs, could be prepared, and then planning would be adequately linked to budgeting.



(Planning's Judgment)



(Management's Judgment)

Figure 15. Management's judgment versus planning's judgment.

Figure 16 shows this decision matrix approach to objectives and programs.

The decision-maker will use such decision matrices when planning provides them. These matrices should be an end product of the physical planning efforts like the state highway plan and the numerous other transportation plans.

FINANCIAL OPERATING SYSTEM

Defining the Linkage Among All Operations

The main link between headquarters and the operating divisions is financial. This essential financial link is a reporting system that can be relied on to alert management

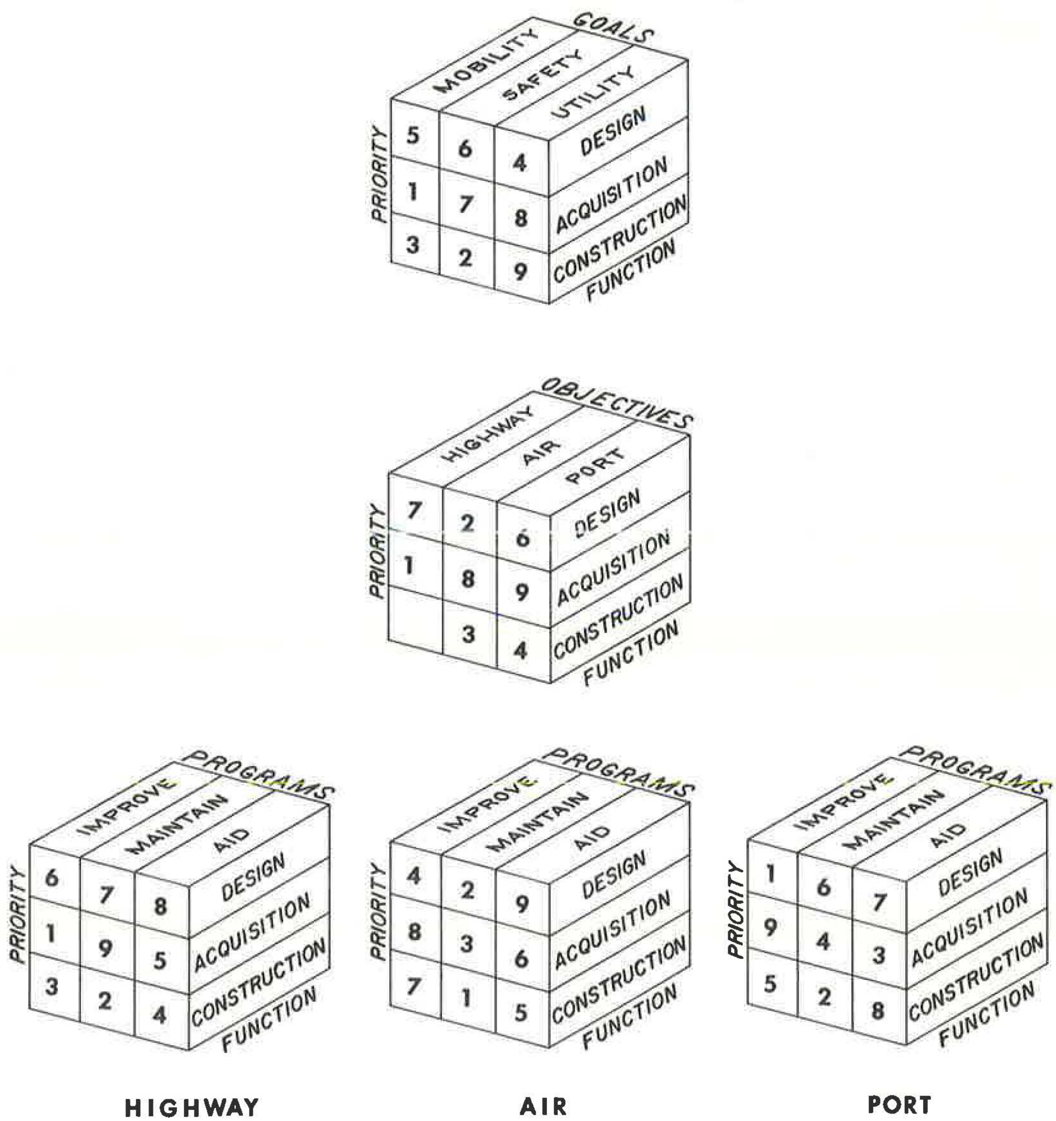


Figure 16. Decision matrix approach to goals, objectives, and programs.

quickly to problems and unusual occurrences at the division level.

To set up this reporting system, the accounting and other internal information-gathering methods of each operation must be compatible. This is an arduous process.

The complexity of establishing a reasonably foolproof financial reporting system is so intricate that even those who have struggled hardest and longest with it still make mistakes. But without such a system management has to accept pretty much on faith such data as the operating divisions are able and willing to supply.

The Basis for Improving Financial Reporting

The legal or fiscal requirements for most state governments are similar. States usually require central accounting by legislative appropriation and a series of standard objects for expenditures. This accounting information satisfies the legislative control requirements and provides the basis for line item budgeting.

However, such information does not adequately provide for lower level operational control. For example, in most states, highway project accounting is supplemental to central accounting. This supplemental accounting system has been created to improve management reporting about highway contracts. The task today is to make the supplemental systems compatible and integrated with the legal or fiscal accounting.

To improve financial reporting, the accounting method should be used to (a) create the budget, (b) charge expenditures against the budget, (c) provide legal or fiscal accounting, and (d) report performance to management.

Accounting starts by setting up the budget. This begins in the decision-making process by describing the groups of activities that we call projects. Forms are used to describe the project and its resources. The resources can be extended into dollars, financed with revenue, and reserved in a planning and funding file as authorized for charging. In Wisconsin this is accomplished with a computer procedure shown in Figure 17.

As charges are made against the project budget, they can be compared with the planned amount. Furthermore, the charges can be filed in a general ledger and filed again in transaction order to provide for an audit trail. A computer procedure also maintains these files.

Charges can then be accounted for and balanced against available revenue to satisfy the fiscal accounting and disbursement requirements. We employ a series of off-line computer procedures to provide these analyses and reports.

Information can also be given to management that portrays performance of the various operations. This is provided by reporting the management-oriented information from the plan cost file to the users from a cost-monitoring subsystem.

What has been described are the fundamental elements of our financial operating system (Fig. 18).

Applications of the Financial Operating System

The FOS can be classified as a management services system. As a management services system, the FOS is a network of related procedures that are developed according to an integrated scheme for establishing and accomplishing the objectives of the total organization and its individual units. FOS then is a set of related procedures that are goal- and performance-oriented.

The FOS includes the necessary computer and manual procedures for the integrated planning and accounting of all resources (both dollars and manpower) of the department. When coupled with a management information reporting capability, it provides control at the lowest level of management, the project manager.

The FOS has been expanded to provide information in areas of operational work planning and resource management. It integrates and refines the other subsystems, such as personnel and project scheduling.

The system being developed is believed to be the most advanced highway management information system in the nation. It provides unique features such as the development of project work plans based on standards of performance. This is done by mathematical resource simulation and adjusting of budgets based on actual work performed. In this manner it produces a more definitive analysis of variances by cause and responsibility.

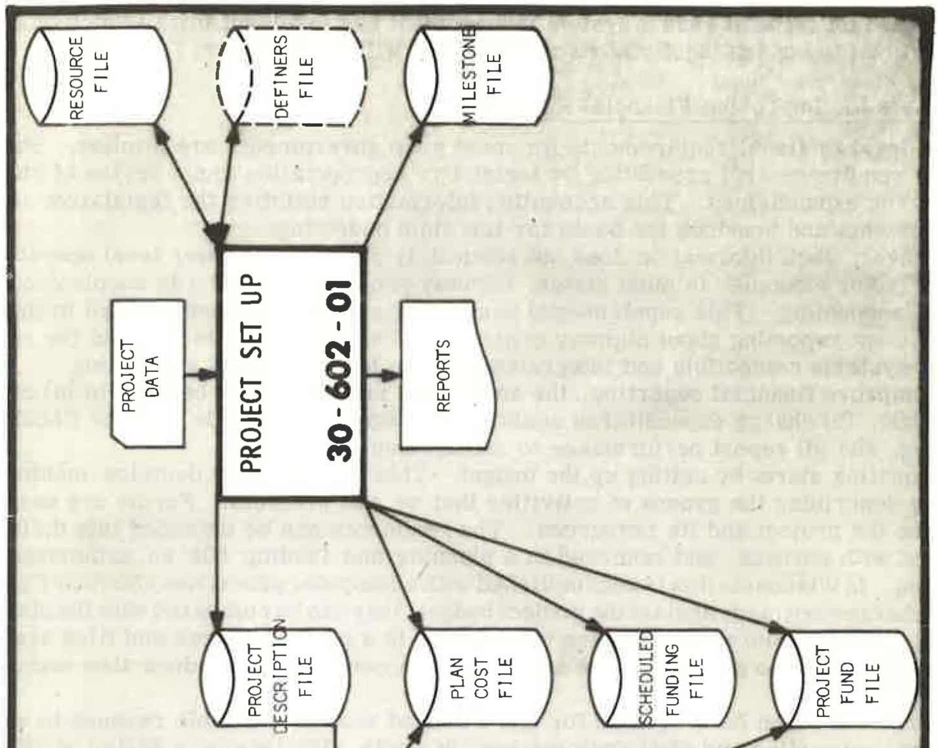


Figure 17. Basic filing subsystem.

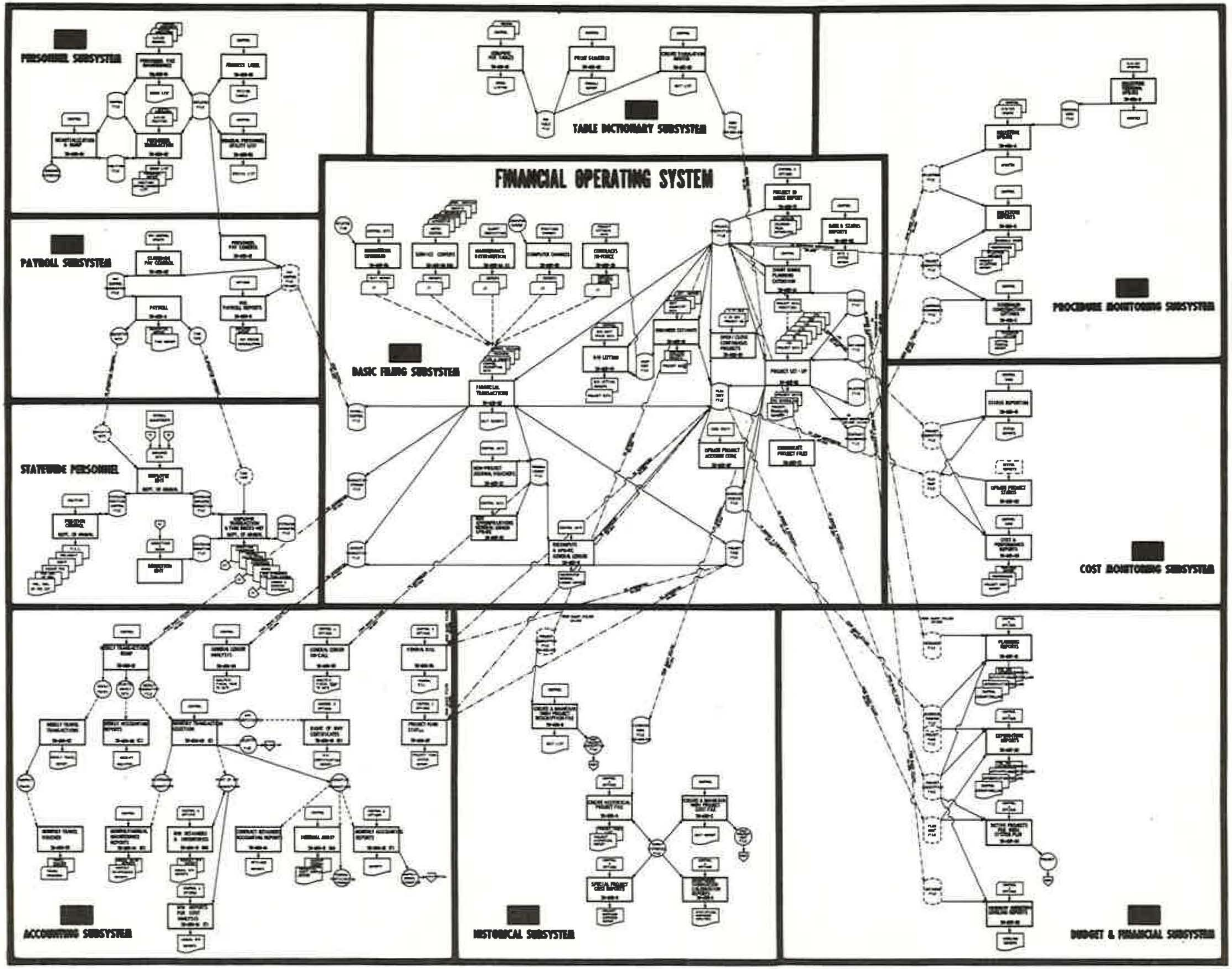


Figure 18. Financial operating system (FOS).

Another key to effective management reporting is making the accounting data conform to a uniform coding structure. This satisfies the diverse needs of the department for financial and management data through basic input codes. Wisconsin's uniform coding structure consists of eight basic codes: appropriation and account, program, project identification, function, organization and responsibility, activity and object, manpower classification, and social security number. Although this depth and detail may seem undesirable, it is necessary to have this information to manage our many operations.

FOS Subsystems

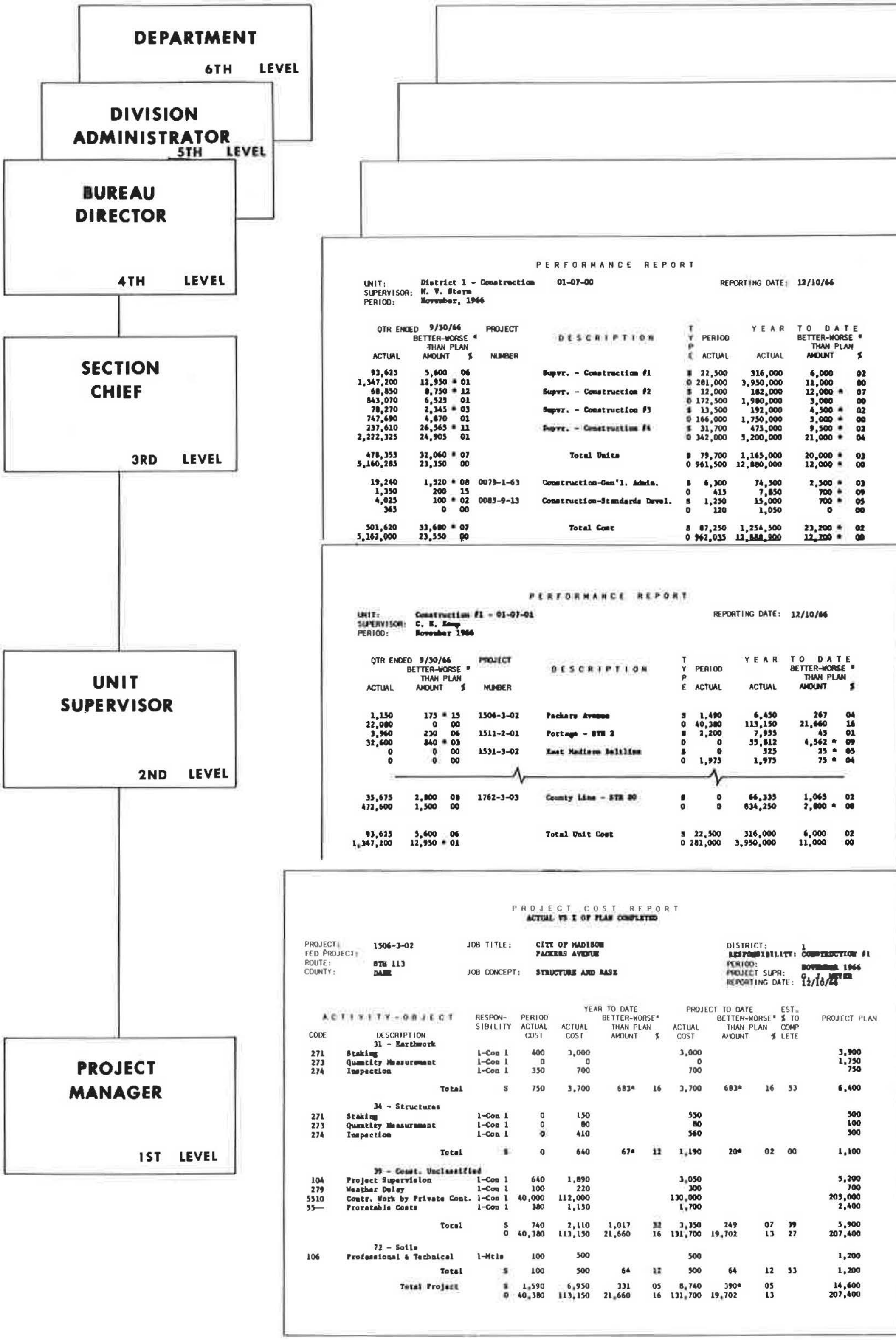
There are nine subsystems in FOS (Fig. 18). These are designed to facilitate the gathering, planning, controlling, and coordinating of the entire integrated accounting system. This information is obtained and presented through the use of electronic data processing. The subsystems are as follows:

1. The table dictionary subsystem—one dictionary exists for all financial procedures. These tables define the standard codes, their descriptions, escalation and payment rates, and standard factors to generate information about all operations. By filing data elements, the financial files can be regulated and updated to current policy.
2. The basic filing subsystem—this is the central files. It creates and maintains all project and financial data for resource planning and accounting. It is an on-line file designed for weekly processing, which provides information 10 days after the end of the week.
3. The personnel subsystem—this is designed to provide employee, personnel, and position processing and reporting within the department.
4. The FOS payroll subsystem—Because the statewide Department of Administration is responsible for payroll checks, FOS needs a link to it. It coordinates personnel, position, and payroll processing and reporting for the Department of Transportation.
5. The accounting subsystem—This subsystem controls the fiscal accounting procedures and reporting methods. It satisfies the department's diverse needs for financial accounting data and meets the legal and management requirements of the department.
6. The cost monitoring subsystem—Because cost reporting is fundamental to any operation, this system is designed to provide line managers with current information for use in controlling and planning their operations.
7. The procedure monitoring subsystem—Key points for decision-making are called milestones. This subsystem will provide management with the means to establish and monitor these production and program objectives by coordinating cost and manpower reporting.
8. The budget and financial subsystem—This provides the necessary information for the annual and biennial budget processes and long- and short-range financial planning. It gives management the data and information for encumbrance accounting, the authorization for operating expenditures, and program planning.
9. The historical subsystem—This is the processing link to the highway network data and information system. It maintains historical records of the department's expenditure program in order to establish trends and other environmental analyses.

Management Reporting Philosophy

With all this information available, our reporting system still must allow for oral communication within the organization. The most effective management is still on a personal basis.

Accordingly, FOS reporting techniques do not provide all the information to everyone. It does, however, provide all the information needed within an organization. For example, we report detailed financial costs about a project to the lowest level of management (the project manager). These reports are line item budget and expenditures separated by manpower and other costs. The supervisor of several project managers receives only a summary report for each project. If he wants details he must "talk" to his project manager. A section chief receives a report that summarizes budget and expenditures for each of his unit supervisors. Thus, he must "talk" to his subordinates if he wants more detail. This concept of reporting continues up the chain of command (Fig. 19).



PERFORMANCE REPORT

UNIT: District 1 - Construction 01-07-00
SUPERVISOR: H. V. Storm
PERIOD: November, 1966
REPORTING DATE: 12/10/66

QTR ENDED 9/30/66 ACTUAL	BETTER-WORSE * THAN PLAN AMOUNT	%	PROJECT NUMBER	DESCRIPTION	TYPE	PERIOD ACTUAL	YEAR TO DATE ACTUAL	BETTER-WORSE * THAN PLAN AMOUNT	%
93,625	5,600	06		Supvr. - Construction #1	S	22,500	316,000	6,000	02
1,347,200	12,950 *	01			O	281,000	3,950,000	11,000	00
68,850	8,750 *	12		Supvr. - Construction #2	S	12,000	182,000	12,000 *	07
843,070	6,525	01			O	172,500	1,980,000	3,000	00
78,270	2,345 *	03		Supvr. - Construction #3	S	13,500	192,000	4,500 *	02
747,690	4,870	01			O	166,000	1,750,000	3,000 *	00
237,610	26,565 *	11		Supvr. - Construction #4	S	31,700	475,000	9,500 *	02
2,222,325	24,905	01			O	342,000	5,200,000	21,000 *	04
478,355	32,060 *	07		Total Units	S	79,700	1,165,000	20,000 *	03
5,160,285	23,350	00			O	961,500	12,880,000	12,000 *	00
19,240	1,520 *	08	0079-1-63	Construction-Gen'l. Admin.	S	6,300	74,500	2,500 *	03
1,350	200	15			O	415	7,850	700 *	09
4,025	100 *	02	0085-9-13	Construction-Standards Devel.	S	1,250	15,000	700 *	05
365	0	00			O	120	1,050	0	00
501,620	33,680 *	07		Total Cost	S	87,250	1,254,500	23,200 *	02
5,162,000	23,550	00			O	962,035	12,888,900	12,200 *	00

PERFORMANCE REPORT

UNIT: Construction #1 - 01-07-01
SUPERVISOR: C. E. Kamp
PERIOD: November 1966
REPORTING DATE: 12/10/66

QTR ENDED 9/30/66 ACTUAL	BETTER-WORSE * THAN PLAN AMOUNT	%	PROJECT NUMBER	DESCRIPTION	TYPE	PERIOD ACTUAL	YEAR TO DATE ACTUAL	BETTER-WORSE * THAN PLAN AMOUNT	%
1,150	175 *	15	1506-3-02	Packers Avenue	S	1,490	6,450	267	04
22,080	0	00			O	40,380	113,150	21,660	16
3,960	230	06	1511-2-01	Portage - STH 2	S	2,200	7,955	45	01
32,600	840 *	03			O	0	55,812	4,562 *	09
0	0	00	1531-3-02	East Madison Beltline	S	0	525	25 *	05
0	0	00			O	1,975	1,975	75 *	04
35,675	2,800	08	1762-3-03	County Line - STH 80	S	0	66,335	1,065	02
472,600	1,500	00			O	0	834,250	2,800 *	00
93,625	5,600	06		Total Unit Cost	S	22,500	316,000	6,000	02
1,347,200	12,950 *	01			O	281,000	3,950,000	11,000	00

PROJECT COST REPORT
ACTUAL VS % OF PLAN COMPLETED

PROJECT: 1506-3-02
FED PROJECT:
ROUTE: STH 113
COUNTY: DANE
JOB TITLE: CITY OF MADISON PACKERS AVENUE
JOB CONCEPT: STRUCTURE AND BASE
DISTRICT: 1
RESPONSIBILITY: CONSTRUCTION #1
PERIOD: NOVEMBER 1966
PROJECT SUPR: C. J. [illegible]
REPORTING DATE: 12/10/66

CODE	ACTIVITY-OBJECT DESCRIPTION	RESPONSIBILITY		PERIOD ACTUAL COST	YEAR TO DATE ACTUAL COST	YEAR TO DATE BETTER-WORSE* THAN PLAN AMOUNT	%	PROJECT TO DATE ACTUAL COST	PROJECT TO DATE BETTER-WORSE* THAN PLAN AMOUNT	%	EST. % TO COMPLETE	PROJECT PLAN
	31 - Earthwork											
271	Staking	1-Con 1		400	3,000			3,000				3,900
273	Quantity Measurement	1-Con 1		0	0			0				1,750
274	Inspection	1-Con 1		350	700			700				750
	Total		S	750	3,700	683*	16	3,700	683*	16	53	6,400
	34 - Structures											
271	Staking	1-Con 1		0	150			550				300
273	Quantity Measurement	1-Con 1		0	80			80				100
274	Inspection	1-Con 1		0	410			560				500
	Total		S	0	640	67*	11	1,190	20*	02	00	1,100
	39 - Const. Unclassified											
104	Project Supervision	1-Con 1		640	1,890			3,050				5,200
279	Weather Delay	1-Con 1		100	220			300				700
5510	Contr. Work by Private Cont.	1-Con 1		40,000	112,000			130,000				205,000
55—	Proratable Costs	1-Con 1		380	1,130			1,700				2,400
	Total		S	740	2,110	1,017	32	3,350	249	07	39	5,900
			O	40,380	113,150	21,660	16	131,700	19,702	13	27	207,400
	72 - Soils											
106	Professional & Technical	1-Mtls		100	500			500				1,200
	Total		S	100	500	64	12	500	64	12	53	1,200
	Total Project		S	1,590	6,950	331	05	8,740	390*	05		14,600
			O	40,380	113,150	21,660	16	131,700	19,702	13		207,400

Figure 19. FOS cost and performance reports.

No central "supersnoop" receives all reports. Thus the Secretary of Transportation and on down must consult his organization to obtain detailed information.

Continuing Budget Approach

We have developed our department's legislative budget for the past and present biennium by using a program budget format and approach. We submitted this budget using only the existing legislative authorized programs. We call this our "continuing program budget". New programs are introduced to the legislature separate from the formal biennial budget. By using this approach, the new program can be analyzed for effect on the "continuing budget". This approach eliminates the sometimes confusing zero base budget, inasmuch as it clearly identifies new and continuing programs. This approach is a real key to a successful transportation legislative program.

SUMMARY AND CONCLUSION

The program budget and financial operating systems satisfy the two principal purposes of governmental budgeting. They are the focus for rational policy decisions and are tools for effective management. The budgetary process is associated with every phase of planning from the identification of major goals to the selection of immediate priorities. This process must be involved in the conduct of current operations because results cannot be appraised without it. PBS and FOS also determine how to best allocate scarce resources among competing needs and indicate how effectively they are used.

We have emphasized that one of the primary purposes of program budgeting is to provide the manager with better information for decision-making. This requires a common language for communication, which is attained only through education, orientation, and personal involvement. Based on this language, information can be generated to guide the decision-maker. Decision-making is dependent on good judgment because it involves the real world and real people. This PBS decision-making is generally at a high-level and therefore must be easily communicated to the people who need it and in a usable form. A uniform method of accounting is necessary. This reporting must also be timely, so we have to modernize our entire accounting system.

Although this is a relatively simple process, it has taken Wisconsin 4 years from conception, 3 years since we started, and 1 year of operating under both the old and new environments to reach our present stage. It has cost us $1.2 million for this development. We will probably not be operating smoothly for another 3 years, but we have seen some of the results.

One of the best results has been in terms of everyone's attitude in helping to improve operations and services. Because of this, we are now operating as a team with greater success in solving problems. Another important development is that we are acting as one department, dedicated to serving all the transportation needs of the state of Wisconsin. But to improve by changing 40-year-old methods takes time and effort. The changes will come only through tireless effort and dedication on the part of many. We at Wisconsin are providing the necessary effort and deepening our dedication. We know we shall succeed; a profitable and productive future depends on us.

Systematic Approach to Project Development and Computer-Aided Design

W. J. KERTTULA, Wisconsin Department of Transportation

The decision-making process that precedes construction is called planning. Briefly, this process is the development and establishment of a set of goals, the selection and approval of a set of improvement projects, and the investigation and design activities required to realize the goals. This process leads to the actual highway improvement activities of land acquisition or site construction or both. The first step of goal formulation is called comprehensive planning. The second, third, and fourth steps are called project development functions, which are the detailed implementation of the transportation plan. There are four steps involved in project development: (a) long-range planning, the definition and selection of specific objectives as workable projects; (b) design investigation, the refinement of the long-range planning; (c) design process, i.e., the management procedure and engineering process for producing contract plans for an improvement project; and (d) precontract administration, the processing of the contract plans prior to execution of the improvement construction.

The project development system has been well received because of two major characteristics: The policy statements and revisions can be in the hands of users within 36 hours, and formal documentation in the Design Manual can be easily revised and updated without upsetting the overall organization. Computer-aided design, the highway design system, will be accomplished by systematic development of computer technology toward the goal of creating a numeric surface approximating the earth's surface on which any number of designs may be superimposed so that the optimum design may be achieved.

•FOUR YEARS AGO we decided to improve our services to ensure economic benefits to highway users by creating an integrated operations system. We latched onto such phrases as increase decision-making before the fact, emphasize management by exception, eliminate the resistance-to-change factor, and integrate our operations to respond as a system.

We then established our overall objective: to define those steps required to process improvement projects from inception to the point at which they can be executed or advertised and let to contract. By accenting decision-making and assuming that the technical processes of engineering would continue to improve, we felt that we could create an effective project development system (PDS).

PROJECT DEVELOPMENT

Establishing our Project Development Objectives

Before making a change, we had to be certain a change would be an improvement. After all, we had been producing plans for highway work during the entire history of the department, and all personnel involved in the course of events could look with pride on the accomplishments.

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Advances in methodology and technology, in addition to the wide array of electronic data processing equipment, were now available. Coincident to this, new concepts were being applied to the transportation field: joint development, multiple use, diagnostic teams, environmental control, aesthetic quality, sociological impact, cultural effect, economic considerations, and many others. Recognizing many new factors to be coped with and opportunities for even greater demands prompted us to examine our methods to be certain that, in fact, we were equipped to meet the complexities of the future.

To make a self-analysis, we prepared flow charts of all activities involved in producing a set of contract plans. The chart had to show every minute effort or activity from the time someone, somewhere in his own mind, instigated a highway improvement, until that same project, through the multitude of actions and reactions of all the people involved, became translated into a set of plans.

The completed charts showed that the process being used involved too many reviews by too many people. Reports were being prepared at meaningless stages lacking in authoritative decisions. Sometimes a change in mind resulted in the work up to that stage being redone because the action taken was too late in the process. We were producing plans through a continuing process of planning, programming, surveying, preliminary planning, and final design. The process was not devised to provide management decision at any one strategic point or phase. Neither did it readily submit to budgeting or scheduling because it was lacking in predetermined staging. There was no question about the need for revising the process to fit a systems approach.

We were quick to recognize that the PDS must be a decision-making system and not one of approvals. This assumes that the efficiency and overall effectiveness of project development would improve if we increased decision-making before-the-fact and alerted ourselves to the exceptions to these decisions as we perform.

Second, we established that any subsystem of project development should have specific end products. Accordingly, any general terms presently used to describe the end products must be clearly defined.

Third, decisions must be made at the lowest possible level of management. The effective and long-lasting decisions made at the highest level of management should be made early in the operations process. The subsequent technical decisions can then be made by the supervisors developing the plan.

Fourth, the adopted state highway and functional system plan for 1990, and the improvement projects that are derived from it, should be the policy framework on which operational procedures are constructed.

Fifth, the PDS should be directed toward long-range rather than short-range limiting factors.

Sixth, guidelines and standards should be developed to define operational and technical requirements. These guidelines and standards must provide an effective means of training our staff as well as a means of control to ensure that the planned objectives will be met. Highway standards should be developed to cover a period of time in the future to ensure that efforts will not have to be expended readjusting plans based on spur-of-the-moment standards.

Finally, individual activities or processes that are a part of the PDS should fully employ modern systems techniques.

What Are the Components of Project Development?

A system can be defined as an array of related activities that contribute to a common purpose. Project development, while a major subsystem of IOS, is a system in that the common purpose of its many activities is to provide varying degrees of project planning information (statewide to site highway plans) for management action prior to execution and realization of a highway improvement for Wisconsin's motorists.

Our present project development system consists of four essential operating subsystems: long-range planning, design investigation, design process, and precontract administration. I would like to briefly identify the activities currently included in the PDS.

Figure 1. Comprehensive planning.

Figure 2. Project development—long-range planning.

Actual highway construction follows as an outcome of a process with three elements:

1. Development and establishment of a set of goals,
2. Selection and approval of a set of improvement projects, and
3. Investigation and design activities required to realize the goal.

These steps yield the improvement project—the actual highway activities of right-of-way acquisition and/or construction.

The IOS approach is classifying the goal formulation process as comprehensive planning. (An example of goal setting is the development of the state highway plan.)

The state highway and functional system plan was our first before-the-fact decision (Fig. 1). We had now placed all the highways in our jurisdiction into systems and functional classes. For these same highways we have made projections in the degree of access control, traffic volumes, operating speeds, interchanges or intersection types, and, to a degree, corridor location. This information is now available to all concerned even before a section of highway is selected as a candidate in the long-range program—truly an advancement in decision-making before the fact.

SUBSYSTEMS OF PDS

Long-Range Planning Subsystem

Long-range planning comprises four major activities:

1. Translating needs into specific projects,
2. Establishing the project objective,
3. Determining administrative direction (in terms of relative urgency), and
4. Developing an improvement plan (6 to 10 years in advance).

It is in this first subsystem, long-range planning, that we select the projects to be developed. We have said that long-range planning is the definition of the state highway plan into workable projects, i.e., selection of specific objectives (Fig. 2). The activities include the establishment of statewide production goals according to highway function, jurisdiction, finance, and priority.

The end product of long-range planning is a continually current priority list of improvement projects, including the project description and a general cost estimate. The projects selected for the list represent our attainable statewide goals. For this reason we say that the improvement project is conceived in this subsystem.

Design Investigation Subsystem

Our second subsystem, design investigation, is the heart of the PDS. This is where an improvement project becomes a reality. This is the point at which we transfer a project from the long-range planning subsystem (from the goal category) into design investigation, where it becomes operational and committed.

Five major activities are included in design investigation:

1. Agreement on project objectives,
2. Development of alternative criteria,

3. Selection of design criteria,
4. Provision of attitudinal direction, and
5. Establishment of project objectives and schedules.

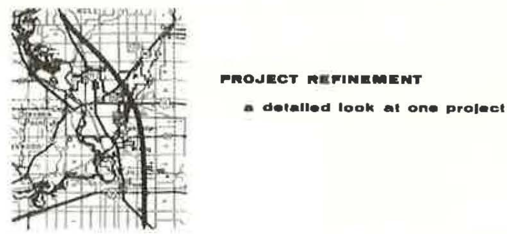

Figure 3. Project development—design investigation.

It is this area that demands critical and exacting decisions because here is where the project is subjected to detailed study and close examination. Top management carefully analyzes it with respect to budgeting, scheduling, and reasonableness. Following closely are the exposure to and assignments of the latest engineering techniques. In other words, design investigation is the refinement of the projects selected as potential improvements in long-range planning as shown in Figure 3.

Design investigation is the refinement of the state highway plan—involving location planning and socioeconomic and cultural studies—to facilitate highway (line) location and to achieve agreement on the geometrics and structural design criteria as well as the project limits and elements.

We have given design investigation clearly defined end products. The investigator need only report back to long-range planning for decisions on deviations or exceptions to the state highway plan. These end products include project termini, refined location (one step removed from surveying in the field), construction staging, land acquisition staging, pavement type, and intersection and access treatment. As many design standards as practical will be selected and the first realistic cost estimate developed during design investigation.

The design investigation will then provide management with the clearly defined and agreed on concepts of a highway project to be constructed during a specified future year, hence the term committed to construction.

Design Process Subsystem

Our third subsystem, the design process, is the management procedure and the technical and engineering processes followed for the production of contract plans for construction. In accordance with the systems concept for development, we established specific objectives for the design process.

Early in the design process, we conduct an operational planning meeting. At this meeting the goals, set down in the design investigation and approved by the Commission, are reviewed and reconsidered to see if they are still applicable.

In Wisconsin, the major part of designing is done on a decentralized basis, that is, in each district office. The districts are responsible for the production of the contract plan. The central office design engineer, whom we have labeled the monitor, is responsible for ensuring that the predetermined objectives are met.

Therefore, the district office and the monitor operate in close coordination and have a shared responsibility to maintain statewide uniformity. This dual process is continued throughout the preconstruction stages of design development.

There are always problems that require management by exception because it is not feasible to produce procedures and standards that will cover all situations. Because each project is unique, there will always be some need for management by exception. We fully expect deviations from the normal. Therefore, PDS has provided for early recognition of and early authority for the exception decision so that inaction will not delay the project. Channels must be provided so that the exception can be brought directly to the level of management having the authority to act quickly on the matter.

One key for all engineers to remember is that each project is unique. A series of design exhibits will be prepared as necessary for each project representing the decisions that have been made. We can only predict the conditions we expect to encounter by a thorough design investigation.

For example, what happens if the monitor and district office disagree on a design or if they have a difference of opinion or a difference of judgment on a particular portion of the design? When we have exceptions to our standard procedures, detail drawings, or design, the district engineer is responsible for resolving these exceptions. If, in his judgment, he feels that he would rather leave this decision to a higher level of management, he may refer it to the office of the state highway engineer.

In addition to this exception procedure, Wisconsin has a modified line-staff organization where the district engineer is responsible directly to the Highway Commission. If, in his judgment, he would like to review or appeal a decision, he has recourse directly to the Highway Commission.

This, then, is the basis for the authority structure in the PDS.

Precontract Administration Subsystem

The fourth and last procedural subsystem, precontract administration, includes processing the contract plans prior to starting construction. Precontract administration is a formularization of the results that includes cost evaluation, finance clearance, and contract plan printing and distribution to bidders. Precontract administration begins when the plans, specifications, and estimates (PS & E) are received in the central office. Remember, all design decisions have been made or should have been made before getting to this phase.

The acceptance of the construction site plans, contract specifications and construction quantity, and cost estimates are required to release the project to advertise for bids. This subsystem ends when the construction contract is awarded to the bidder.

Computer-Based Engineering Methods Subsystem

The four previously identified steps have been selected as the operating subsystems of the project development system. The defined information flow among activities within the subsystems provides the base for the project development formal procedures.

Concurrent with project development, the technical methods required to support the decision-making were reviewed to ensure that they were efficient and effective. These technical methods, because they contribute to the achievement of project development, were called the highway design subsystem (HDS).

The general objectives of this process are improving and simplifying our operations by having routine decisions made at the operational level. Highway design then becomes the computer-based engineering tool. The components largely act as a generator of data during the actual physical design phases of highway improvement projects.

The next question that we must ask is, How do we computerize and integrate this operation? To accomplish this we developed the HDS to ensure that the procedures of project development are fully integrated.

By performing many of the routine tasks, this system expands the creative capacity of the engineers, technicians, and draftsmen. These designers then have the opportunity to spend more time determining and establishing the best possible design for a particular project. It is then easier to conceive the most economical and socially acceptable designs. An added benefit is that it reduces the manpower requirements.

The highway design system presently consists of two individual engineering programs: Integrated civil engineering system, coordinated geometry (ICES COGO) and roadway design. ICES COGO is a program for the computer solution of geometric problems in any area that involves points, lines, curves, and polygons in two-dimensional space.

Roadway design is capable of producing the following:

1. The designed roadway template listing for a single roadway facility with up to nine adjacent and independent roadway facilities simultaneously;
2. The earthwork quantities for each roadway separately or combined with any adjacent roadway;
3. The plotting of the original cross section with the proposed template superimposed on it; and
4. Either the plotting or the printing of the mass diagram.

We also plan to expand the program's capabilities to include most of the other routine engineering problems.

The conception and implementation of the PDS are major breakthroughs in modern decision-making.

With the aid of other elements of the Integrated Operations System, we have established an overall competence and confidence in ourselves. All of us who have worked together to see the culmination of goals and activities know what lies ahead. There is more work, more struggle, even more frustration. But, more importantly, there is advancement and accomplishment—success. We will continue on our plotted course to seek more utility with increased energy through greater economy.

The Highway Network Data and Information System

T. J. HART, Wisconsin Department of Transportation

The highway network data and information system (HNDI) supports the transportation planning process, a major function of the Wisconsin Department of Transportation. Although the system is a principal tool in the planning process, it was designed to interface with the project development and program budget systems. HNDI provides the capability for efficiently collecting, processing, storing, and displaying highway-related data and information for all public roads in Wisconsin. In the future it will be expanded to integrate all modes of transportation.

The numerous individual data files of the total information system are coordinated through a common indexing scheme. The maintenance of the control indexes and the data files is the responsibility of those units of the organization whose function relates most closely to the data being filed. The indexes, their file location, data validity, timeliness, and uniform data definitions are a part of the systems operating procedures for the data sets available to users of data and information.

Users of the system will be able to assemble and relate data from within HNDI from other department systems and format the information according to their individual needs. The display of this information in a graphic format will give staff and management a clear and concise picture of pertinent information for an efficient analysis of highway planning problems.

•THE INTEGRATED OPERATIONS SYSTEM (IOS) is being implemented by the Wisconsin Department of Transportation as a long-range series of innovative development projects. The IOS consists of a number of management and computer-based subsystems that will ultimately form a total system of efficient procedures and information processing designed to facilitate the operations of the department. The highway network data and information (HNDI) system was designed as an integrated subsystem within the framework of the IOS. HNDI is the computer-based component of IOS and, together with the planning system (the procedural component of IOS), will provide the data information analysis and direction required to service the transportation needs of the state.

RELATIONSHIP OF HNDI TO THE PLANNING SYSTEM

Government today talks about the budgetary process and the resource allocation decision resulting from a planning-programming-budgeting system (PPBS). The effectiveness of this resource allocation decision is directly proportional to the level of guidance provided to those doing the resource estimation. Management must provide this guidance by determining what tasks are involved in the accomplishment of the goal, when the tasks must be completed, and who will perform the tasks. Thus, strategic objectives are set, priorities are established, and responsibility is assigned. Guidance, then, results from a systematic approach to the planning process, the Department of Transportation's planning system.

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Our planning system consists of three performance areas around which we have organized the department's division of planning. This system is composed of the following areas (Fig. 1):

1. Policy planning, which is concerned with the economic or policy analyses required for strategic planning; this function determines the operational rules and cost consequences of existing and proposed department actions.
2. System planning, which involves the physical planning process required to develop the goals for state transportation; this function develops system plans by mode, area, and jurisdiction to guide the department's action.
3. Program planning, which determines the level of service selection and priority ranking processes required to establish specific objectives for state transportation; this function develops specific priorities for transportation projects in order to establish work programs for the department.

Figure 1. Performance areas within planning division.

Policy, system, and program planning are all dependent on the availability of accurate information, which is supplied by the HNDI system.

The planning system requires certain resources to ensure performance quality. A problem arises because planning deals with goals and objectives—resources that cannot be assigned a dollar value. Budgeting requires specific resource costs. Consequently, the planning system requires a great deal of data and information about the state and its transportation users to facilitate the establishment of values for policies, goals, and objectives. Furthermore, data and information themselves must be recognized as vital resources, as vital for budgeting as the standard resources, men and money.

It follows that planning is based more heavily on value judgments than on dollar or manpower resource values. Many categories of data and information are necessary as a basis for making these judgments. Obviously, management must be provided with the means for efficient collection and storage of these data and the resultant information. The HNDI system is the central repository of data and technical information for the Wisconsin Department of Transportation.

As a tool, HNDI provides for the storage, processing, and output presentation of information crucial to support the planning function. In addition, it facilitates many of the routine reporting requirements of the department. The State Log used by the department and the public, data required by federal agencies, and vehicle mile summarizations and trend analyses used in the planning function will be largely produced by the computer, releasing personnel for other work.

Basic Criteria for the HNDI System

Data is a general term. For the HNDI system, its definition is both singular and plural. That is, although data are obtained and stored in a single file, they are used by numerous individuals in the performance of their functions. It must be recognized that planning is performed at each of the three performance levels of the department: managerial, functional, and operational. Although the same data item may be required for planning at all three levels, it will probably be utilized differently at each. Thus, planning is performed at all organizational levels, and a data element is multi-used. These concepts are essential for the development of an effective system of data management.

The design of many present data management systems allows processing only within that particular system. This requires considerable duplication of data procurement and storage. To fulfill today's requirements for sharing data, the data must be accessible from all systems through the use of uniform controls. These common controls provide the capability of requesting data from many systems to find necessary answers. For example, information from the financial operating system, the program budget system, the project design system, and other systems will be accessible through the HNDI system.

Obviously, the criteria for the development of a data management system necessitate a very large number of comprehensive data files that require many years to implement. The HNDI system has taken on this impressive task in several stages.

Purpose of the HNDI System

The highway network data and information system is a procedural system designed to provide for coordinated collection, storage, and retrieval of data. As in a library, this information will be cataloged by a uniform method of reference, which will provide the users with readily accessible information in the form necessary to support their functional activities and aid their decision-making. The same data will be available from one common source to numerous users.

For example, the bridge file is one of the 11 current HNDI files. There are 52 data elements included in the bridge file, one of which is vertical clearance. Consider how many users and uses this one data element may have. Vertical clearance information is used as part of the accident analysis procedure. Geometric design of a rerouted highway may require accurate vertical clearances. Many reports required by state and federal governments must include vertical clearance data. The field signing of minimum vertical clearances presupposes the availability of accurate data. Even a public service, providing commercial trucking firms with vertical clearances of bridges on their routes, is accomplished with this one data element.

To reiterate, a single data element must be available to many users at several job levels. A common data source will provide accuracy, control, rapid access, and a reduction in the duplication of activities. The data user will be free from lengthy collection and filing procedures. This independence will increase the quantity and quality of his work. The planning process using HNDI as a tool will become more effective and efficient in its role as definer of the goals and objectives of the department.

Scope of the HNDI System

Implementation of the HNDI system has been guided by management's decision to segregate work into logical stages based on the following:

1. Priorities by the organization for data from the HNDI system,
2. Availability of dollar resources,
3. Capability of existing manpower to conduct self-analysis and innovative development studies, and
4. Coordination with other systems being initiated.

TABLE 1

STAGES OF THE HNDI SYSTEM

Stage	Characteristics	Miles of Road
1	Main lines of state trunk network and connecting streets; municipal boundaries	12,000
2	Main lines of county trunk network and urban extensions; special features off main lines of state and county trunk networks	24,000
3	Local roads (town roads) and local streets (small urbanized areas)	60,000
4	Local streets (large urbanized areas)	9,000
5	Other public roads	500

The first subdivision of work was by mode of transportation. Each mode was then further divided into stages for implementation. The greatest need and biggest problem was for highway-related data and information. Five stages for implementation of the highway data system were established (Table 1).

STAGES OF THE HNDI SYSTEM

Stage 1 data pertain to main lines of the state trunk network, their connecting streets, and to municipal boundaries. Similar data for the county trunk network will be programmed during stage 2, as will special features off main lines. Thereafter, data for local roads, local streets, and other public roads will be added, in sequence, to the system.

At present, the foundation, i.e., the system design, is complete. Stage 1 files are implemented and selected stage 2 files are being initiated. The first data to be filed in HNDI include the following:

1. The state trunk network, which includes those highways on the Interstate, U. S., and state trunk highway systems;
2. The municipality boundaries, which comprise the state, county, town, city, village, and township boundaries; and
3. The special features off main lines, such as roadways and traveled ways of ramps, connectors, frontage roads, weight stations, and safety rest areas.

It is important to note that only a realistic amount of work was selected for initiation, not the whole system. The success of the HNDI system relies on user interest and support even in the initial stages. To create and maintain that interest and support, we must produce a usable product in a short time. Although our initial product is small, it generates new ideas and requirements. Because this is a user-oriented system, the expansion of HNDI will be an on-going user-directed process.

The product of our efforts has been the design of a flexible modular system. Eventually it will satisfy the data requirements of all modes of transportation: air, rail, and water, in addition to highways. This versatility is a natural result of creating a truly systematic approach to data management.

CAPABILITIES OF THE HNDI SYSTEM

The symbolic relationship between man and the HNDI system is illustrated by its data flow, shown in Figure 2. The system has a great deal to give, but man is the most important part of the flow cycle. Whether acting as supplier, inputting data to update a file, or as user, retrieving information to solve a problem, man is the initiator of all activity. He also constitutes a problem, because he speaks a language different from that of the computer. Still, the initiator is the one person this system must satisfy completely. Therefore, two interface steps were created to bridge the language gap.

The interface for input functions is the preprocessor program, which accepts data coded by the supplier on a standardized form developed for his convenience. These data are then edited for certain basic errors and reformatted so that the HNDI file maintenance program can process them. The language gap is effectively bridged.

The interface for output functions is the library, a synonym dictionary that serves a dual purpose. First, it accepts a query in user language and codes it for acceptance by the program generator, which writes a program for retrieval of the desired information. Then, the library accepts the retrieval information from the data base and converts it back to user language for output. Thus, the user is not restricted to the computer's internal processing language, nor is he dependent on the availability of a programmer each time he desires a retrieval.

The value of these interfaces is apparent in the case of changing input and output specifications. If the user's functional operation changes and he wants to modify his input, the only programming change required is in that particular module of the preprocessor. For example, the man in the field collecting data for the traffic characteristics file uses a standardized form that lists passenger vehicles as Wisconsin cars,

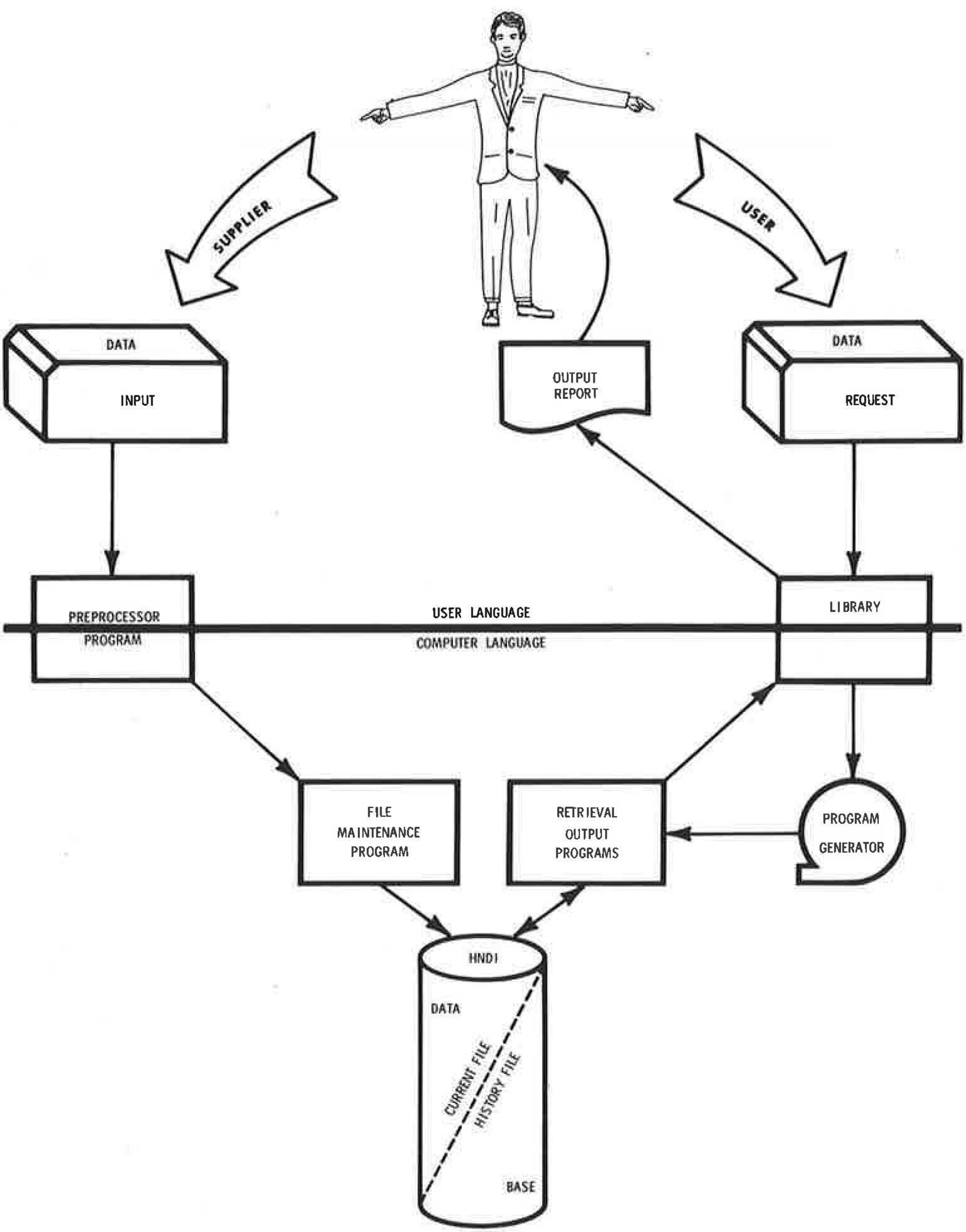

Figure 2. Data flow of HNDI system.

out-of-state cars, cycles, and buses in that order. Under actual field survey conditions, however, the frequency of buses passing stations is several times that of cycles. For ease in recording data, the form can be changed by moving buses to a position before cycles. For this change, only the preprocessor is affected so that it can reformat the data before it reaches file maintenance.

Similarly, should the user wish to vary the programmed standard output format, he can identify his special output requirements in his query cards, and a special program will automatically be generated to satisfy his needs. In the municipality file, for example, the standard output format for ratios of population to land area by county is a listing of county names alphabetically with ratios in a corresponding column. If the user wishes to have the ratios listed from high values to low, he specifies this format on his query cards; he will then receive from the computer a list of counties ranked by their population/ land area ratios.

Of course, there are procedures and changes that involve a much greater degree of reprogramming within the system. Refinement, for example, is the addition of a data element to an existing computer file. In the traffic characteristics file, single-unit trucks are subclassified as two-, three-, and four-axle. Field observation notes that a number of single-unit five-axle vehicles have started to use the road system. A new data field should be added to the traffic characteristics file. This refinement requires changes in the file maintenance program so that it will accept the data and in the library so that it can locate and retrieve the data, as well as the more basic change in the preprocessor for editing. Eventually, we will be able to bypass two of those steps. By completing the description requirements of the library first, the program generator will, in the future, be able to write the preprocessor and file maintenance programs necessary for refinement. Presently being tested, computer-written programs are as efficient as those developed by programmers and have the further advantage of being uniform.

DATA CONTROL FOR THE HNDI SYSTEM

A common indexing scheme is the basis for keeping data complete and united. The HNDI system incorporates three methods for controlling and cross-referencing data: reference points, state plane coordinates, and project numbers.

Reference Point

The first method is a landmark location point on a roadway identified by the highway number, direction, and a sequential number, which together provide unique identification of the point. These points are selected in accordance with specified criteria to maintain a maximum spacing of approximately 1 mile. The reference points are tied to fixed locations and are sequenced with a variable distance. This method was chosen because it is not tied to a fixed distance and thus provides the capability to maintain both current and historical data and ensures that historical data can be readily compared to current. Mile marker and log-mile schemes, which are tied to fixed distances, do not provide this historical capability. Reference points for the state trunk network have been identified on aerial photos and are being marked in the field. These reference points are used for indexing and filing data in the HNDI system and are included as data elements in the files of other systems, such as the program-budget system. Thus, the reference points serve as the common demoninator for linking and supplying data from other systems.

State Plane Coordinate

The second method of cross reference and control, the state plane coordinates, is used for spatial identification of data and also as a support of the system's capability for graphic display of information. Sufficient points are identified along a highway to enable a plotter to produce a representation of the highway or any length of it. The user will often need information output in a readily understandable visual form. The state plane coordinates give us an alternate method of data reporting if, in the future, we find the reference point method unsuitable for certain data storage circumstances.

Project Number

The third method of control, the project number, is commonly used by the operating units of the Wisconsin Department of Transportation in the performance of their daily activities. For example, a length of highway that is being improved will have a unique project number. The inclusion of these numbers in the HNDI system expands the means for communication between the user and the data base, and allows another means to interface the files of other systems.

PLACING THE RESPONSIBILITY FOR THE HNDI SYSTEM

Undertaking a project of this magnitude requires the complete participation and intense involvement of management, as well as operational personnel. As we mentioned earlier, management must provide the means for system development. Management cannot assign additional innovation work to an existing staff and expect a superior product with the allocated time. The Wisconsin Department of Transportation recognized these needs and acted accordingly. Because the system is user-oriented and department-wide in scope, the overall project responsibility was assigned to the Division of Planning. An interdivisional group was established specifically for development and initiation, and a new HNDI section, responsible for the continuity of the system, was created in the Division of Planning.

The end products of this chain of development are operational procedures, deliberately oriented to provide for the integrity of the data. Development of these procedures required careful consideration of the user-computer relationship. To preserve the integrity of data, there should be as little intervention or reinterpretation of data as possible in the interval between data leaving the user and entering the computer.

During data input the supplier is responsible for collecting and coding data for updating and validating the HNDI base. The only intervention between supplier and computer is in the production section, which keypunches the coded data, schedules computer processing, and, after processing, directs input reports to the user. As shown in Figure 3, intervention and the possibility of misinterpretation are minimized.

Similarly, the output process is working toward minimization of intervention between the user and the computer. However, the procedures for eliciting a data response are more complex than the input procedures and, thus, the minimization process is evolutionary.

Initially, the user must identify his request and then communicate it to the HNDI section, which will code the necessary query cards. The cards are forwarded to the production section for keypunching and scheduling. After computer processing, the output is validated and then forwarded to the user. This sequence is shown in Figure 4. As the user becomes adept in the query procedures he will code his own query cards and bypass the HNDI section, eliminating an intervention.

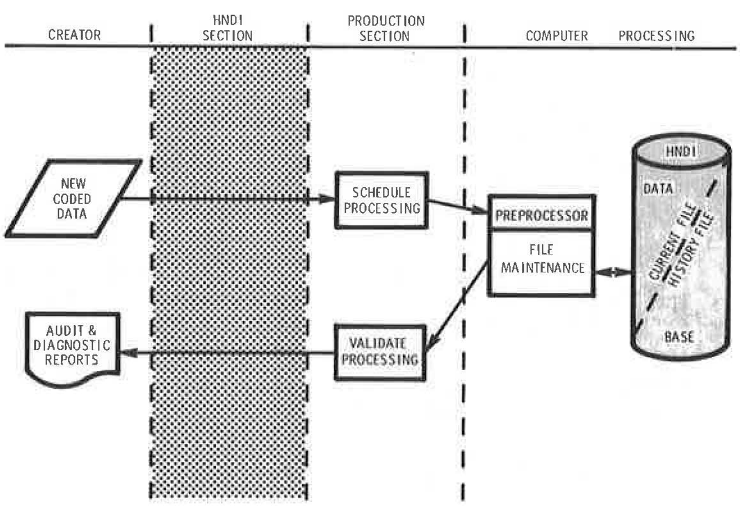

Figure 3. Sequence of data input to processing.

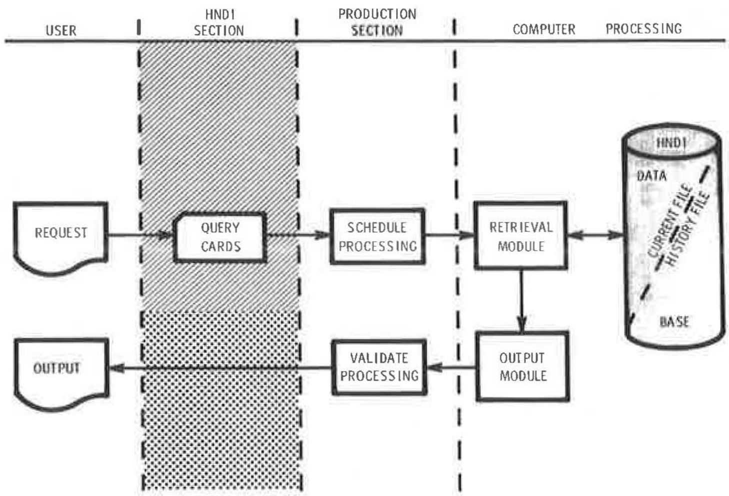

Figure 4. Sequence of current data-retrieval process.

When our system capabilities expand to include terminal processing in the district offices, the user will communicate directly with the computer for data retrieval, as shown in Figure 5. Not only will this represent elimination of all intervention, but it will also reduce greatly the time elapsed between submittal of a query and receipt of output.

SYSTEM GROWTH

The continuance of a system is not limited to operating with what we have today. Because a progressive organization is dynamic, its functions continually change, and its data requirements are not static. The implementation of a flexible system in an organization where obsolescence flourishes is guaranteed disaster. An adaptive innovative climate is essential as a stimulus for the real-time growth of a system.

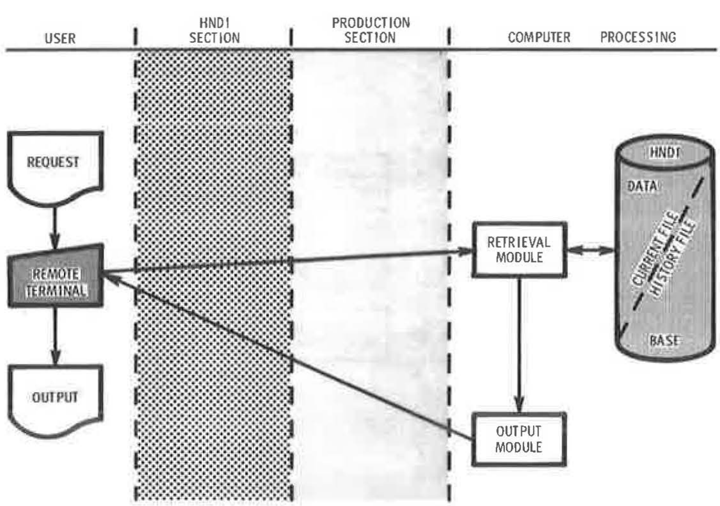

Figure 5. Sequence of future data-retrieval process.

SUMMARY

This is the highway network data and information system. HNDI is not merely computers, programs, and personnel. It is a capability to satisfy the data needs of all planning for use today, with the flexibility to meet the needs of tomorrow. It provides coordination, procedures, and control for efficient communication between the user and the computer. It was developed through participation, consultation, and involvement in an atmosphere of creativity. HNDI is the means to do a better job.

Wisconsin's Computer System for Integrated Operations

M. L. BACON, JR., Wisconsin Department of Transportation

A principal reason for the Wisconsin Department of Transportation's leadership position is that it has developed computer applications in which over 1,000 computer procedures are presently in operation. Because of the large volume of work planned under the Integrated Operations System, the computer system of problem-solving is an absolute necessity. The computer planned for use is a multi-processor 360 model 65.

The system is represented graphically by a wheel. The spokes designate the major computer-based systems. The next portion, which is connected to the spokes, represents the various systems to be completed within each of the major systems. The external rim of the wheel designates the different data-based constants or controls that make possible the linking of the numerous subsystems. The wheel indicates the vast amount of varied information that can be supplied to management. This computer system makes it both feasible and possible in the future to correlate data within a single computer system. This is the most obvious and necessary use of the system, because it will give the user the data from many different subsystems in the most usable format, an important condition to the decision-making process.

•THE DEPARTMENT OF TRANSPORTATION is building its future around two basic philosophies: use of the systems approach, and utilization of automated equipment to modernize its organization. The systems approach is the technique used in planning for the Integrated Operations System (IOS). From the IOS came the computer-based Financial Operation System (FOS), the Highway Network Data and Information System (HNDI), and the Project Development System (PDS). The design, development, and implementation of these systems has been a long, sometimes frustrating, and sometimes gratifying experience. To those of us who have been developing these systems and to those who have been using them, it would seem that our systems have caused more problems than they have solved. We have all sometimes felt a desire to return to the "good old days".

Wisconsin, with its IOS and advanced use of data processing, is recognized as a leader in the field. What does this mean? It means that we have taken the initiative to develop new ways to solve problems. It means that we have learned by our mistakes. The type of frustration that we have all felt is that of challenge and not that of the "good old days". In the good old days the attitude was, "Well, that's the way it's always been done" or, "That's close enough for government work". I prefer the challenge of today.

We still have a long way to go before we can say that the job is done. When we consider advanced technology, we realize that we will never be completely caught up. The success of the systems approach has been not the computer programs or the new procedures, but the continuing development of the people involved, individually and collectively. We also have the knowledge gained by our experiences, which gives us the ability to do a better job today and prepares us for the problems of tomorrow. My evaluation of our systems approach is one used in the promotion of the state of Wisconsin: "We like it here".

Paper sponsored by Department of Economics, Finance and Administration and Department of Urban Transportation Planning and presented at the 49th Annual Meeting.

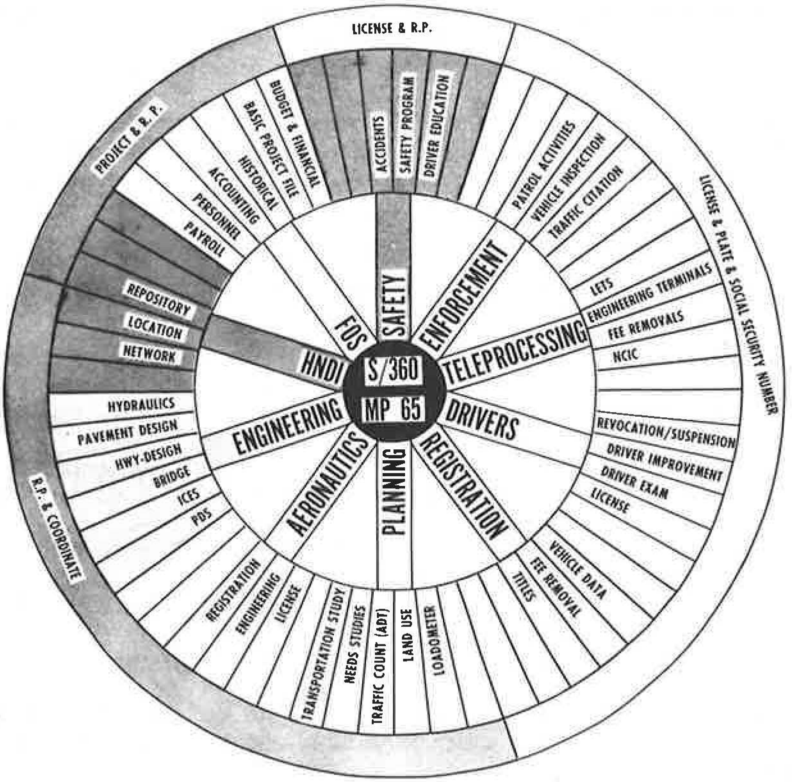

Figure 1. Wholly integrated transportation system.

The automated equipment we are using is not limited to the computer but includes new testing equipment and new survey equipment. One of the primary reasons we have realized the fullest benefit from use of the computer is that we have used the computer as a tool—a tool to assist and help man perform his tasks more efficiently.

INTEGRATED SYSTEM FOR TRANSPORTATION

A wheel best describes the overall concept of what we are doing and where we are going (Fig. 1). This concept shows that the Department of Transportation will have a uniform integrated data base system that will provide accurate, timely, and meaningful data that we can use to make decisions. This data base will be developed around the capabilities of an IBM system 360 multi-processor 65 (MP65). Thus, the computer is the hub of the wheel. The spokes of the wheel are the 10 major data processing systems defined for the department. Some of these systems have been very well defined, as in the case of FOS and HNDI. Others are, at this time, in various stages of development and will change as development continues. Some of the systems, like the FOS, are highly integrated while the engineering system can be best described as a series of individual or independent systems such as COGO and divided highway. As development continues, new spokes may be added or spokes may be deleted. The ideal system would eliminate as many unnecessary systems or procedures as possible.

The rim of the wheel designates the subsystems of each system. These subsystems are again divided into logical segments for development and implementation. For example, the accounting subsystem is divided into 15 procedures, each procedure being defined as a computer run that can contain a variable number of programs.

The tire of the wheel represents the data base constants, which are elements of the data that allow us to manipulate data within and among systems. These are the factors that hold the wheel together and allow us to correlate all information available concerning a particular problem.

The manipulation of data within a single system is not new, but the concept of having data from one system feed into another system is new. This means that one system, to operate, is dependent on another one. We still have a lot to learn and need new hardware and software to make this capability fully possible. We have, however, taken the "one small step for man" in this direction.

Let us take a look at how this concept may work in the near future. Suppose that we wanted to evaluate a specific section of highway to determine its relative safety. We would build a data model of that highway as follows:

1. Establishing the limits of our model by using the reference point system, we query the accident file of the safety system for all accidents in our model area.
2. From the planning system, we can get traffic volume and traffic characteristics data.
3. The accident data contains the driver's license number and vehicle plate number. This allows us to query the driver file to get the records of all drivers involved in the accidents.
4. Once we have the plate number, we can query the enforcement system, vehicle inspection file, and get vehicle inspection records.
5. Using the plate number, we can also query the registration file and get the records of the vehicles involved in the accident.
6. From the engineering system, we can get details on alignment and bridge characteristics.
7. Through the capabilities of the HNDI system, we can get details of the highway such as surface type, width and condition, width of shoulders, and other standard highway characteristics.

Once we have developed and tested our model we would then have a means to perform our analysis. We could change the traffic volume factor to see what effect this would have in conjunction with the other factors on the accident rate of this highway. By manipulating these factors, we could tell what best course of action could be taken to lower the accident rates. For example, we might find that increased driver training would do more to reduce accidents than reconstruction of a highway. Or, if large percentages of the vehicles involved failed to pass vehicle inspection tests, it means that more stringent vehicle inspection and enforcement would do more to prevent this type of accident. These types of analyses would then be the basis for developing a balanced program budget that would give us the greatest return for our investment.

By establishing minimum values for these factors, we could evaluate the entire files to find locations that are critical—perhaps before they exist and not after. This type of analysis is impossible today but not in the future. Utilization of techniques such as these will allow us to get the best results for the money available and to have some standards on which to base consistent long-range goals and objectives. Equally important to the hardware and software capabilities needed is the training of managers and technicians to utilize these new capabilities.

WISCONSIN'S COMPUTER SYSTEM

At present the Wisconsin Department of Transportation is utilizing five computer systems. These systems are in separate locations and are not compatible. So, if we are to implement an integrated system, we must have a compatible computer system. This compatibility is being accomplished by the installation of the MP65 system, which will be operational by February 15, with conversion from all existing computers completed by July 1, 1970.

Why the MP65 Computer System?

Of special significance is a requirement of our integrated systems that the data be stored on-line with the computer and available 24 hours a day, 7 days a week. A highly sophisticated computerized file is of little value if someone turns off the power or the system fails for any reason.

Some of the significant differences between our present computer and the MP65 system are as follows:

1. The MP65 gives us a more efficient system in that it provides a single supervisor program, advanced software techniques, and more efficient hardware. With the use of MVT (multiprogramming with variable number of tasks), it gives growth potential and compatibility.

2. The MP65 has special operating characteristics as compared to a single-computer system. As the name implies, the MP65 is two central processing units working together. It has seven data channel paths, large main core memory, and dual control unit paths to I/O devices. This means more efficient utilization of the power of the central processing unit—more throughput.

3. The failure of one processor will not cause the system to fail, as the other processor will automatically pick up the work of the first. The core units are separate modules from the processor, and again failure of a single position or module of one memory will not cause the entire system to fail. Because of this configuration we can continue to operate in a degraded mode while performing maintenance on or trouble shooting the equipment, thus eliminating downtime. For special operating needs, the system can also be operated as two separate computer systems.

4. The system is configured so that we can get to any one device from two channel paths, some of which is automatic, some of which requires manual switching. This not only provides backup but increases the overall efficiency of the computer. We can expect a throughput of one and a half to two and a half times that of two single model 65 computers.

In support of the normal computer hardware we are making maximum use of terminals so the users can have direct access to the computer and its files.

The 2260 terminal is used to visually display data stored in the computer. It is also used as a means to enter data directly into the system. A 1050 terminal connects our nine district offices and the bridge section to the computer. All engineering calculations are performed through the terminal as opposed to the batch methods. This gives the engineer the use capabilities of the large computer and the ability to have direct access when he wants it, just as if he had his own computer.

The volume of work or use of the computer increased when the terminals were installed as compared to when the same job was sent in by mail. In this case the turn-around time was reduced from 5 days to 10 minutes.

A teletype terminal is used by law enforcement agencies to query the driver and registration files for law enforcement activities. This would allow an officer, for example, to determine if the vehicle is stolen before stopping the car.

Some of the other major pieces of off-line equipment used in conjunction with the computer are

1. Calcomp plotter, 50-ft drum—used exclusively for plotting X-sections;
2. Calcomp plotter, 4- to 6-ft flatbed—used for general plotting such as bridge and culvert drawings; and
3. A two-dimensional digitizer for recording data.

Also, a special coordinate readout device is attached to a Kelsh plotter used to record cross-sectional data from aerial photographs.

WHAT DOES THE FUTURE HOLD?

First, we must implement existing systems and train our managers and technicians to utilize these new tools. Then we must continue to develop new methods and procedures to keep pace with new problems and some of the old ones that still remain. The future holds new and exciting adventures for those who are willing to accept the responsibilities. This outline gives an idea of some of the concepts and philosophies used by the Bureau of Systems and Data Processing in its part of the development of the department's Integrated Operations System.