Systematic Approach to Project Development and Computer-Aided Design

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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.