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These **Digests** are issued in the interest of providing an early awareness of the research results emanating from projects in the NCHRP. By making these results known as they are developed and prior to publication of the project report in the regular NCHRP series, it is hoped that the potential users of the research findings will be encouraged toward their early implementation in operating practices. Persons wanting to pursue the project subject matter in greater depth may obtain, on a loan basis, an uncorrected draft copy of the agency's report by request to the NCHRP Program Director, Highway Research Board, 2101 Constitution Ave., N.W., Washington, D.C. 20418

INTERACTIVE GRAPHIC ROADWAY DESIGN SYSTEM

Functional Specification and Feasibility Study

An NCHRP staff digest of the essential findings from the final report on NCHRP Project 20-8, "Interactive Graphic Roadway Design System," by C. W. Beilfuss, T. A. Dwyer, and R. M. Phillips, Control Data Corporation.

THE PROBLEM AND ITS SOLUTION

The sophistication of computer techniques employed by the highway engineering community has shown steady growth. Even with this growth, the engineer has not been able to realize the full potential of the computer because of restrictions on the capability to interact with the machine process and interject judgment at appropriate points in the process. These restrictions are a direct result of the manner in which information is transferred between the designer and the machine.

Although improved techniques and procedures making extensive use of computer and computer graphics technology have been developed to enhance highway location and design, there is a need for a designer/computer interaction capability using new graphic display evaluation techniques and providing for rapid and easy revisions based on the designer's judgment throughout the process of the highway design. The designer/computer interaction is the ability of the designer to make discrete changes to design parameters as a result of evaluating graphic displays, static or dynamic, and directing the computer to modify all stored data and produce revised displays that reflect the design parameter change. One prominent design evaluation capability under development by others is the ability to produce a variety of computer-generated graphical displays, including animated perspective views of the highway based on computer design information and actual terrain data as part of an automated roadway design system.

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Therefore, the total research objective envisioned for Project 20-8 was to develop an interactive computer graphics software system capability for use by the highway designer in effecting revisions at appropriate points in an automated roadway design process. No hardware development was intended. The software system developed was to be broadly applicable and written in a programming language that would minimize hardware dependency.

The total research objective as originally conceived was to be achieved through several phases of development, the first of which was carried out and included a review of procedures and techniques derived from previous research and development on an automated road design system. Existing interactive computer graphics applications for uses other than highway design were to be studied and a software system design that would describe in detail the software required to achieve the total research objective previously stated was to be developed. The software system design was to be in such form that programming efforts could proceed directly in a subsequent phase of development. Lastly, an analysis of computer and graphical display hardware requirements necessary to support a software system design was to be made.

At approximately the one-third point of the project the objectives were modified to place emphasis on the economic feasibility of developing an interactive graphic road design system that was to be useful and economically justifiable. Every reasonable effort was to be made to avoid designing the interactive software for one specific hardware configuration or application program and to keep the engineering procedures general. Orientation was to be toward engineering procedures rather than toward computer software or hardware, and various combinations of computers, display devices, communication ties, and software were to be examined in the hope of identifying the unique combination providing the highest benefit/cost ratio. Engineering procedure was defined to mean those operations that an engineer would desire to perform to effect interaction in the computerized design process. The automated roadway design system used in conjunction with the interactive system would serve only as a data generator that would allow the engineering procedural research to be performed. Therefore, there was no intention to evaluate the relative merits of existing automated highway design systems. The Road Design System developed by the Texas Highway Department was to be used as the prototype interfaced application program.

The Control Data Corporation findings are defined explicitly enough in the project report to provide an administrator with good insight as to what an interactive graphic roadway design system can do, what it will cost, and how long it will take to become operational. They are useful to an administrator or decision maker concerned with allocating resources to the development of more sophisticated and efficient automated highway design. The feasibility findings are based on many assumptions; therefore, each user will have to make an independent evaluation as to how the findings may be adapted to his own circumstances. Because the project consisted of determining the feasibility of developing an interactive graphic roadway design system, the findings probably are of limited interest to the practicing engineer.

FINDINGS

The research concludes that an interactive graphic road design system (IGRDS) that will provide the engineer with a flexible design tool is feasible. It will provide computations for horizontal alignment geometry, vertical alignment, terrain data management, detail roadway cross-section modifications, general geometrics, and displays of plan views, profile views, cross sections, perspectives, and earthwork diagrams.

The procedures of use are the key to the design of a system such as IGRDS. They must completely satisfy the users' needs for each step of design. The procedures for IGRDS are represented by a structured set of commands from which the user may select the desired system action. The command structure has been systematically presented by a user command state diagram. This command structure may be expanded or otherwise modified to fit organizational needs.

The design of the system must take into consideration several important variations in the way an organization operates, such as:

1. Location of design activities, centrally or in district offices.

2. Differences in existing computer power.

3. Assignment of control over the computing services within the highway organization or elsewhere.

To satisfy the needs to design in several district offices, IGRDS software was designed to have one component reside in the central (host) computer with the Road Design System and one to reside in a smaller terminal computer at the remote site. Telecommunications would tie the two computers together.

The software was designed to provide flexibility and permit the substitution of commands and/or road design systems. Specifications are not related to a specific computer or display device but are described to fit a particular category of displays. Development of software specifications was limited, due to project resources, to functional rather than detailed definition programs. The nature of the software is such that not only is it based on the needs of a specific road design system, but it also can be made to perform with different commands, display images, or for a different design function, such as bridge design, by replacing particular modules to the program. The analysis of system hardware components included the variables of the main computer, terminal computer, communication linkage, and display device.

It is estimated that by the time IGRDS is ready for general use, 50 percent of the state highway departments will have an adequate computer for the IGRDS main processor.

Each agency using IGRDS will be required to acquire an interactive graphic display device and a terminal computer. Which type of terminal configuration is selected will depend primarily on whether a terminal must be installed in each of several offices or only a central installation will be required. Based on the cost and performance analysis, the higher-cost, high-performance display would seem better for the single central installation and the lower-cost device better for the multi-device installation.

The use of IGRDS in a state highway department appears to be justified. The estimated yearly value of return and direct labor is somewhat in excess of the estimated cost of operation. Indirect benefits in terms of reduced cost in construction and other identified terms would appear to provide more than adequate justification.

To reach the total research objective, several more steps of development are required. Introduction of IGRDS into highway department offices on an operational basis should be possible in three years, and IGRDS will be composed of seven major components. These components are:

1. A large (or host) computer system.

2. Operating system software for the host computer.

3. An application program system (road design system) operational in the host computer.

4. Interactive graphics hardware, possibly including a small or mini-computer for controlling the display device.

5. Standard interactive graphic software delivered with the hardware.

6. User roadway design commands; the intangible procedural capabilities effected by interactive graphics roadway design software.

7. Interactive graphics roadway design software.

It appears that the minimum host computer than can support both standard batch processing and IGRDS is an S360/50 with 524K bytes of memory and secondary mass storage equal to 117×10^6 bytes (Note: The large amount of central processing unit memory available on a model 50 is 524K. Additional units of lower-speed core storage can be added; however, processing cannot take place in these units. They may be used for storage of data arrays and pages of main memory.) Less power than this will be inadequate to achieve the desired application program calculation rates that will have an adequate memory for the interactive graphic software, the roadway application program, and standard batch jobs.

There are a large number of computers made by various manufacturers that can fill the role required by the terminal computer. The range includes:

1. The mini-computer, costing about $20,000 and occupying about 2 cu ft of space.

2. The familiar small engineering computer.

3. The larger process control computer.

All that is required to make a device acceptable as the terminal computer in IGRDS is good speed and interrupt capability. It is helpful if the device has software including an assembly language and a FORTRAN compiler. It is advantageous if a computer can also act as a remote job entry terminal for those organizations that want to process both interactive graphic and batch jobs from remote districts.

The random scan device appears to best satisfy the user requirements as the type of display to be used for IGRDS when the system is of a small number of terminals, and full or nearly full utilization can be anticipated. The method of use that would most clearly satisfy a high utilization is centralized design.

When many decentralized design groups must be served with justification based solely on IGRDS, the storage tube would probably be a more practical selection from a cost standpoint.

To achieve a completely functional and useful system, the following steps beyond the feasibility study and functional definition accomplished under Project 20-8 are required:

1. Complete the system and program specification.

2. Develop programs and perform preliminary testing of the system.

3. Test and refine the system in a prototype highway laboratory.

4. Install and maintain the system for production use.

The cost of development of IGRDS software is estimated at $460,000, a cost that could be jointly underwritten. The total yearly use cost for a highway department is estimated at $156,000, and direct design labor saving is estimated at $192,000 per year. Additional indirect benefits to road users, construction costs, maintenance costs, programming costs, and drafting costs totaling several times the direct labor savings would not be unreasonable to assume. The researchers believe that benefits of this magnitude are achievable and would, by generally accepted yardsticks, provide an appropriate return on the investment.

They further believe that the development of IGRDS is feasible if modest enough goals are established. A tested single random scan prototype system is feasible in 2 1/2 to 3 years. The installation of a single-device system in 10 highway departments would be feasible within the following two years. About this time it would seem reasonable to expect the first multiterminal version of IGRDS to be operational. Similarly, the offering of IGRDS service from commercial service operations via wide band would seem reasonable.

In summary, the development of IGRDS seems feasible and justifiable.

APPLICATION

Because the first phase of Project 20-8 was primarily a feasibility study, the findings have no present use to the practicing engineer; however, they are of use to administrators and decision makers responsible for budgeting funds for the development of sophisticated computer techniques that can aid the highway designer; they do lay the groundwork for further development of IGRDS to operational status, including cost and benefit estimates; and the functional specifications for the development of IGRDS will be of interest to engineers and researchers working in the subject area.

The findings are explicit enough to be of value to administrators and decision makers. Complete details of the economic analysis of each of the components of IGRDS are presented in the report and should be of value to those agencies interested in further development of IGRDS. The findings related to feasibility of IGRDS are based on many assumptions; therefore, each user will have to make an independent evaluation as to how the findings may be adapted to his own particular circumstances.

Because of the funding needed, time requirements, and extent of the work necessary to develop an interactive graphics capability that would be widely accepted by highway departments, the remaining phases of work toward the total objective will not be carried out at this time.