ROADWAY DESIGN RESEARCH PROJECT
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FINAL REPORT

by

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This research study was a joint undertaking between the Connecticut Highway Department and the University of Connecticut. Computer costs were defrayed in part by the University of Connecticut and in part by National Science Foundation Grant GP-1819.

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Introduction

On May 1, 1968, the Division of Design in the Connecticut Highway Department submitted a proposal to the Joint Highway Research Advisory Council for research in computer-based roadway design systems. Specifically, they proposed that a small pilot design project be undertaken using the ROADS (ROadway Analysis and Design System) subsystem of ICES (Integrated Civil Engineering System), a software system developed at MIT for IBM System/360 computers. This undertaking was suggested as a Joint Highway Research project between the Connecticut Highway Department and the University of Connecticut because of the availability of an IBM System 360/65 with 512 K storage at the University; an IBM 360/40 with 128 K storage is the smallest computer upon which ROADS can be implemented.

The Joint Highway Research Advisory Council approved the project as a research activity for the academic year, September, 1968, through June, 1969. The staff for the project was to be made up of a liaison engineer from the Connecticut Highway Department to serve as project supervisor, one or two Graduate Research Assistants, if available, from the University of Connecticut to handle the data processing, and Dr. Robert Dawson of the University's Civil Engineering Department to coordinate the activities of the Graduate Research Assistants. A budget of $2,500 was to be allocated for the project.

A copy of the research proposal submitted by the Division of Design and Approved by the Joint Highway Research Advisory Council is attached as Appendix A.

On June 19, 1968, the Division of Design submitted a modified research proposal to the Joint Highway Research Advisory Council at the request of the Executive Research Board of the Connecticut Highway Department. The modified proposal was an expansion of the scope of the project to include TIES(Total Integrated Engineering System) and UNMES(Utah and New Mexico Engineering System). (UNMES has since been incorporated into TIES). Although this expansion was logical, it was unlikely that any system other than ICES-ROADS could be implemented in the specified nine-month period.

Log of Research Activities

Division of Design Activities

In mid September, 1968, Mr. John Spaulding of the Division of Design, serving as the liaison engineer, furnished a card deck of the digital terrain data for Connecticut Project 91-92, a one and one-half mile design project on Route 25 in New Hartford. No ROADS command data were provided with the terrain data, and this proved to be somewhat troublesome because of the absence of Graduate Research Assistants at the University who were familiar with ROADS.

Civil Engineering Department Activities

At the start of the study in September, 1968, there were no Graduate Research Assistants available at the University of Connecticut who could be assigned to this roadway design research project to implement the system on the IBM 360/65 and to conduct

the data processing. Mr. Walter Adams, an undergraduate engineer, was hired part-time in place of the two graduate students that had been anticipated. It was, therefore, necessary for Dr. Dawson to set up a two-month training period to familarize Mr. Adams with ICES in general and with ROADS in particular. This perhaps made the project more realistic in terms of appraising the difficulties that would be encountered in the typical highway design office in as much as the personnel in such an office are not familiar with ROADS either. As soon as he had been familarized with the roadway design system he prepared the necessary ROADS commands data cards that had not been furnished by the Division of Design.

Preparation of ICES-ROADS System

Simultaneously the ICES-ROADS package was ordered from IBM, and loaded into UConn's 360 System. This took approximately two months. There was a delay in obtaining the magnetic tapes of the ICES system, and there was further delay due to the decision process involved in establishing priorities so that ROADS could be maintained on a direct-access storage device on UConn's 360 computer. Several other systems including ICES-STRUDL, had to be removed from direct-access storage to provide space for ROADS. (In April, 1969, the capacity of the direct-access storage devices was increased four-fold and during the month of June, ROADS will be loaded into permanent storage on the 360 system.)

It was thought that ROADS system was ready to run in early December when the staff in the UConn Computer Center was able to prepare the sequence of Job Control Language Cards that must precede each ROADS run in order to gain access to the ICES ROADS

System (or to gain access to any other 360 software system). Several attempts were made to run an example problem, but difficulty was encountered in gaining access to the ROADS system in the 360 storage. Approximately two weeks were spent scrutinizing and modifying the JCL (Job Control Language) cards on the assumption that an error existed in the JCL card set-up. The problem was finally traced to a defective disk storage device upon which the ROADS system resided. In late December the ICES-ROADS system was ready for processing the first highway design problem.

Test Runs with an Example Problem

Before any computer runs were made using the data from the pilot Project 91-92, the ROADS "Example Problem" that is supplied with the ROADS system was run extensively to test various ROADS options. (See MIT Report R68-1, ICES ROADS I, A General Description). As can be noted in the above mentioned report the execution time is very long for this short example problem. It required approximately 20 minutes for processing 4400 feet of two-lane roadway on UConn's 360/65. Most of this time was spent in program acquisition and data transfer. Mr. John Langell, a computer systems engineer at the UConn Computer Center, made several attempts to reallocate the program and data sets to different storage devices in order to reduce the running time. And although he was successful in reducing the running time for the example problem from 20 minutes to 6 minutes on one particular run, no additional runs could be processed. The reallocation process apparently caused data and/or program to be destroyed so that it was essential to go back to the original set-up in order to continue the pilot project analysis.

Design Project 91-92

Following the debugging runs using the Example Problem, the ROADS command data cards prepared at UConn and the digital terrain data cards prepared by the Division of Design were assembled for processing in the later part of January. Several attempts were made before a partially successful run was realized. Difficulties were encountered in the terrain data deck and several cards had to be repunched. Also as expected, there were several errors in the ROADS command data. Until an engineer becomes thoroughly familiar with the structure of the ROADS macro commands (there are several options and/or versions of each command), he is very likely to make mistakes.

The editing of the compilation output and the program correction process was postponed temporarily. Mr. Walter Adams, the undergraduate engineer working on the project, graduated from the University and new personnel had to be found. In mid February Mr. Richard Lemieux, another undergraduate engineer was hired to complete the project. He became familiar with ROADS and made the essential program corrections during February and March, but before he was able to make a successful run several changes were made in the IBM 360/65 operating system. The direct-access storage facilities were changed to increase the system storage capacity, and the OS(Operating System) that the 360 runs under was updated from Version 16 to Version 17. This necessitates the re-loading of ICES-ROADS and the development of a new sequence of JCL cards. Because of the volume of work involved in the numerous conversions for the several software systems in the UConn Computer Center the ICES-ROADS system is not expected to be operable again

until the end of June. At that time the final run can be made on Project 91-92; and it is expected that the program decks are in proper form to give a successful run.

Evaluations

At this point the final evaluations and recommendations are based upon the experiences encountered thus far on Project 91-92, on the ROADS output that was generated in runs of the Example Problem, and on comparisons with output from jobs that were processed with the DTM(Digital Terrain Model) system. The absence of a final successful run is not a major drawback in this cursory evaluation of the ICES-ROADS system. The prime purpose of the study was to appraise the problems that would arise in using the ROADS computer software system as a highway design aid. This goal was fully realized. Although the undergraduate engineering staff that was used on the project obviously was not an experienced engineering team, they were perhaps better versed and more experienced in the use of digital computers and numerical methods than is the typical highway design engineer. They also had experienced personnel to turn to in the event of problems that required highway engineering or computer science expertise.

Implementation of ICES-ROADS

Although the ICES-ROADS system is independent of IBM System/360 equipment configurations, so long as the minimum essential configuration is available, apparently there is still a need for a computer science staff to prepare Job Control Language cards to enable the actual processing of highway design jobs. The suggested

sequence of JCL cards in the ICES write up was not adequate for the University of Connecticut 360/65.

Maintenance of an Operable ICES-ROADS System

The ICES-ROADS system operates as a normal job under OS/360 Versions 5 through 12. There is no assurance that it will continue to operate successfully as OS/360 is up dated. The evaluation activities at UConn were conducted under OS/360 Version 16. Toward the end of the project the UConn 360 system was switched to OS/360 Version 17. The essential changes are yet to be made by the UConn Computer Center staff to put ICES-ROADS back into operation. However, this staff has pointed out that the up-dating process could become impractical with future versions of OS/360. Because MIT, the originator of ICES, is no longer actively engaged in improving, developing, and/or modifying the ICES system there is no assurance that the system will be a good long-range investment. Of course this disadvantage could be overcome if a "User-Group Staff" was organized to carry on such activities.

Engineering Usage of ICES-ROADS

ICES-ROADS would be a sound investment, barring operational problems, only if the highway design staff would become familiar with, and adept in the use of the system. Unfortunately, the Division of Design did not participate in the preparation of ROADS command data. The ROADS language is a problem oriented language. As pointed out by Mr. Louis H. Klotz of the Civil Engineering Computer System at the University of New Hampshire(1):

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(1)Louis H. Klotz, "On the Application of ICES and Universal Program Software Systems," Civil Engineering--ASCE, February, 1969, pp. 72-77.

> This assists the user by permitting him to use the same type of words he may use in conversation with another engineer. However, the sentence structure is not truly conversational since there are formats to be followed. While this requires very careful reading of the subprogram manuals, it has not been found to be a serious drawback in their use. For the novice and student user, the observation has been made that using a problem oriented language approach is very advantageous and a valuable educational procedure. As the user becomes more experienced, however, some of the word requirements, even using the allowed abbreviations, become somewhat tedious and tiresome, particularly with increasing problem size.

A general purpose highway design system, such as DTM, that is programmed in the universally known Fortran Language is undoubtedly more efficient. The user has only to become familiar with the data input format to use the system. Although this approach has less appeal from an educational point of view, the experienced user who is more interested in results is relieved of the repetition and wordiness of a problem oriented language.

Computer Requirements and Processing Time

The ICES-ROADS system is compatible with just IBM System/360 computers that have a minimum main storage capacity of 128 K bytes and at least 2-IBM 2311 disk storage devices. This large storage requirement is attributable to the complexity of the problem-oriented ICES Language. In addition the processing or execution time for an ICES-ROADS job is as much as 5 to 10 times as great as that required for processing a design job with a universal system such as DTM. This comparison, of course, is exclusive of programming time. And as noted above the programming time for an ICES-ROADS job greatly exceeds the data preparation time for a system such as DTM.

Recommendations

Based upon both the limited research experiences implemanting ICES on an IBM 360/65 computer and upon past experiences with DTM, it is recommended that the Connecticut Highway Department should not continue to experiment with ICES-ROADS. The Division of Design has already gained extensive experience with DTM; they should expand the capability of their current version of the DTM system using the 1964 MIT Four-Tape DTM System as a guide, and/or explore the advantages of the TIES roadway design system (essentially UNMES) that is similar in concept to DTM.

The ICES-ROADS roadway design system is for the most part an outgrowth of the DTM system. The outward distinctions between the two systems is basically a distinction between a problem oriented language processor and a data processor as noted above. There is no difference in power between the two systems. When an engineer does the "coding" for a problem oreinted language processor such as ICES, it is often inferred that he is preparing the processing logic. This inference is false. The conversational codings merely serve as calls for pre-programmed computational subroutines that are nearly identical to the DTM data processing subroutines.

Research Project Costs

The expenditures encountered in this cursory examination of the ICES-ROADS and charged to the Joint Highway Research Project were only $523.58. This sum covered the salary for the undergraduate engineers engaged on the project. There was no charge for consultations with Dr. Robert Dawson of the Civil Engineering

Department and Mr. John Langell of the UConn Computer Center. Computer processing costs on the IBM 360/65 system were defrayed partially by the University of Connecticut and partially by National Science Foundation Grant GP-1819.

APPENDIX A

Joint Highway Research

Roads Subsystem of ICES

May 1, 1968

Dr. R. A. Horton

G. S. Koch

I propose that a Joint Highway Research Project be initiated for the problem stated below. It would be appreciated if your committee could approve the project so that it could commence in September 1968.

PROBLEM STATEMENT

Several software packages for computer aided roadway design have been developed for "third generation" computers. In anticipation of the installation of such a computer in the Department's data center, it is necessary to gain experience in the use of these computer programs so that efficient use may be made of them at the earliest possible date. Implementation of the ROADS (Roadway Analysis and Design System) program which is a part of the ICES (Integrated Civil Engineering System) package developed at MIT is proposed on a "pilot project" basis.

FACILITIES REQUIRED

Presently, an IBM 360, Model 40 or larger is needed to implement the ICES system. The University of Connecticut Data Center has an IBM 360, Model 65 available. The ICES operating system has been made available as have two subsystems, CGGO and STRESS. The ROADS subsystem could be added to the package.

PERSONNEL REQUIRED

The data for the pilot project could be prepared by the design personnel who are in charge of design. A liaison from the Division of Design would be appointed to supervise the project. Key Punching could be done in the Department's Data Center. One or two graduate students from the University of Connecticut, if available, could handle the data processing at the University. Dr. Duncan of the Civil Engineering Department staff is generally familiar with this design system and has indicated interest in seeing the project undertaken.

FINANCES REQUIRED

It is proposed that $2,500 be allocated to finance this project from September, 1968 through June 1969.

PREVIOUS ACTIVITIES BY THE DIVISION OF DESIGN IN THIS FIELD

During the past year, Mr. John Spaulding, a Highway Senior Engineer in this Division, has done similar research in implementing and testing the use of DTM (Digital Terrain Model)

for our present computer, a Univac III. Mr. Spaulding undertook the research for his Master's Thesis which was recently submitted. TAM, which is a forerunner of the ROADS subsystem is presently being used in the Division of Design as a result of this research. Our success with this system prompts us to continue to implement a more powerful and all-inclusive system to further increase the productivity of the Highway Design Section.

I will be pleased to furnish any additional information which you may require to consider this request.

George S. Koch

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