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An architectural computer system was developed using modern small scale computers, to ease the interaction and conflict within the design team during the design process. The original proposal included an information file, a mathematical building model, and a subsystems (electrical, cost estimating, etc.) model. Due to unanticipated problems, the system was reduced to a limited building model, a material systems file, and a cost estimating capability with additional subsystems to follow soon. The system, as now operating, is of greatest value in cost estimating, giving a day-to-day cost picture. (JT)

THE COMPUTER AND THE BUILDING DESIGN PROCESS

Presented at the A. I. A. Architect-Researchers' Conference
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A little over a year ago Mr. Darby and myself were discussing the fact that the majority of the engineering departments in Reynolds, Smith & Hills were making extensive use of the computer. These departments had been using the computer as a design tool for about 9 years and many programs had been written by their personnel and ours to solve complex and highly repetitive problems. Such applications as Pipe Stress Analysis, Heat Balance Calculations, Building Frame Analysis and Highway and Bridge Design applications were being used on a day-to-day basis. As you all know, these are extremely well structured problems and lend themselves well to computer solution. However, the Architectural Division was making very little use of the computer. At this point, I think it would be appropriate to describe the basic organization of Reynolds, Smith & Hills.

The firm is functionally divided into 7 divisions: civil, environmental, mechanical, electrical, construction administration, special projects, and architectural. The engineering divisions are responsible for projects which are substantially of an engineering nature and the construction administration division is responsible for construction supervision and inspection of the majority of the firm's work. The architectural division is an autonomous organization consisting of architects, cost estimators, structural, mechanical and electrical engineers, as well as specification writers and clerical personnel. The division is quite capable of pursuing an architectural project from beginning to end without having to rely on the other resources of the firm. Mr. Darby deserves a great deal of credit for the formation of this complete design team several years ago, which I believe you will agree is desirable in light of the tremendous interactive nature of architectural design requiring the close coordination and cooperation of many different individuals of various disciplines.

In discussing the application of the computer to architectural design, it became apparent to both of us that the major problem to be solved concerned the flow of information back and forth within the design team. We discussed the duplication of effort involved in data and quantity takeoffs, and concluded that information required for air-conditioning, lighting design and cost estimating is very similar. These departments had traditionally performed their own takeoffs. Conflicts arose frequently due to changes made to the design by groups within the design team which had an effect on other facets of the design. An example is the inevitable situation where you have an air-conditioning duct going right through a structural beam. Although the computer was currently being used as a design tool in performing rather basic air-conditioning, electrical, and structural calculations, very little use was being made of its power in a total sense. The cost estimating department, which is charged with the responsibility of keeping track of the estimated construction cost of the project as a design develops, was characteristically overwhelmed with work. Unable to keep track of design changes on almost a day-to-day basis, the cost estimators frequently had to relay sad news to Bob concerning projects that had gone over the owner's budget. Cost and design revisions were often the result which, in many cases, compromised the original design philosophy and resulted in drastic revisions to the plans and specifications.

We decided to investigate and evaluate the state of the art of the application of computer techniques to architectural practice, with particular interest devoted to ways and means of reducing duplicate effort within the division and improving the cost estimating process to the extent that an up-to-date construction cost snapshot could possibly be obtained almost on a day-to-day basis on each major project.

Following approval by the principals of Reynolds, Smith & Hills, a four-month investigation followed involving trips by Mr. Darby and myself to several parts of the country, including participation in a Computer Aided-Design Conference at M.I.T. in September, 1966. It became apparent to us that the computer was being used to a very small degree by most architectural firms. As was the case with RS&H, most firms were using the computer as a glorified desk calculator to solve individual engineering problems, not architectural problems. The reason for this once again is quite simple. Engineering problems are well structured; the architectural design process is not. We discovered that a great deal of research was beginning to emerge on a national scale in this area. The problem is being approached from many different angles. Some people, principally from universities, are concerned primarily with the application of graphic display techniques involving cathode ray tubes, plotters and other devices. Others were concerned with simulation and optimization techniques as they apply to human traffic studies and the functional layout of a building. Members of the ICES team at M.I.T. were beginning to attack the information problem and had developed a prototype subsystem for building design called BUILD. It was this development that was of particular interest to us for it represented a frontal attack on the problem area that we wanted to consider; the interactions and conflicts that occur during the design process.

One of the initial criteria that we had established was that the approach which we would follow would have to make use of relatively small scale third generation computer equipment, in particular the IBM 1130. We were admittedly quite frightened by the enormity of the effort involved in producing the initial ICES system and were concerned as to our qualifications in developing an information system utilizing small scale equipment and limited resources. We carefully studied this problem and decided that a system could be developed if certain compromises were made. We were convinced that systems currently under development such as ICES were several years away in terms of being a working tool for the profession, and we needed and wanted to do something <u>now</u>. Also, we wanted to be very careful in designing the system in order that it might fit in well with the concepts of systems such as ICES which are heavily oriented toward time-sharing, man-machine communication and graphical display and manipulation of data. Also, we wanted the system to be operational on a computer which is within reach from the standpoint of economics of the architectural profession at the present time.

A report was presented to the principals of Reynolds, Smith & Hills in December, 1966, outlining our findings and recommending that a small scale information system with computational subsystems be developed. Our original intent was to produce a prototype system by August of 1967 which would contain the following:

(1) An information base which would contain a material file in the computer with relevant information pertinent to materials utilized for a finished structure. Such data as cost, density, coefficients, etc., would be contained within this information base.

(2) A building model which would be a mathematical and descriptive model of a

building describing the current state of the design solution in terms of spaces, surfaces, activities, areas, volumes, costs, etc. This model would be modified and updated as the design moves from the earliest preliminary stages to the completion of contract documents. The material file would be related to the building model by the user in order to describe the components of the structure.

(3) Application subsystems would be developed which would draw upon the information stored in the computer described above. The initial subsystems contemplated at the time were: (a) air-conditioning (b) electrical (c) cost estimating.

The major payoff would be realized from an improvement of communication within the design team as each functional unit contributes and obtains information from this common descriptive model of the structure, hopefully reducing conflicts and duplication of effort.

Input to the computer would involve a combination of simplified input forms and a problem oriented language designed to make full use of current batch processing requirements, as well as being suited for use in a real-time on-line environment.

Wherever practical, full use would be made of existing digital incremental plotters in use now by CSI for plotting framing plans, floor plans and perspective drawings, and other information suitable for graphical output.

As the development progressed, it became apparent to us that data management problems associated with the development of the building model were enormous. The actual programming involved in tying all of the individual three dimensional spaces within a building together was going to involve a great deal more effort than we anticipated. We were able, without much difficulty, to set up a design oriented language to define the individual spaces, but were faced with a tremendous degree of effort in the data management area. One problem of course was the limitation imposed on us by the computer equipment which we were working with in terms of main memory and secondary storage restrictions, as well as its speed.

In the Spring of this year we reevaluated our approach and discovered that it was not really necessary to tie these spaces together in order to realize many of the initial benefits we hope to obtain from the system. This greatly simplified our effort and in August we were able to produce not just a prototype, but an operational system involving a limited building model, a material systems file, and a cost estimating subsystem. The cost estimating subsystem is currently in use by Reynolds, Smith & Hills and they are already realizing tremendous benefits in terms of increased throughput in the estimating department, reduction of human errors and almost a day-to-day cost picture on their projects.

A lighting subsystem is currently being incorporated into this system and will be operational before the end of the year. The air-conditioning subsystem is in the very preliminary stages and should be incorporated by Spring of next year.

As you can see, we typically underestimated the amount of effort which would be required and in some respects missed our original target date. You gentlemen in the audience who are experienced in dealing with computers can appreciate this problem. I am certain that the company which we lease our computers from is fully aware of what the phrase "Software Slippage" means.

At this point let me briefly describe the system at its current stage of development.

A material systems file is maintained in secondary storage containing standard material types and costs which will be applied to vertical and horizontal surfaces, as well as unit items such as windows, doors, etc. This file can be altered or added to by the use of English language statements containing the relevant numerical data. This of course is necessary in that many projects require special material of a nonstandard nature, and it is often necessary to update cost factors, coefficients, and other information. During the early development of the design, the cost estimator or designer describes using English language statements such as SPACE, LENGTH, HEIGHT, etc., each individual space in the structure. The spaces do not have to be symmetrical in any way, can have drop ceilings, sloping ceilings, and can be non-rectangular with any number of sides. Provision is made for doors, windows and other openings, and dimensional information can be entered in either feet, inches, and one-sixteenth of an inch or decimal fractions. Free format input is utilized thus reducing considerably human error and facilitating preparation of data. At the present time the space designation file or building model, if you will, is maintained externally on cards due to limited secondary storage on our present equipment. This restriction will be removed in December of this year when additional secondary storage is added to our computer. Updating the building model at the present time involves modification of a deck of cards but will soon be a matter of simply entering modifiers into the computer.

Once the spaces and special items have been defined and the data prepared on punched cards, complete construction cost estimates can be obtained in the form of computer tabulations. Every effort has been made to organize these tabulations in such a way that they can be readily understood by cost estimators, as well as other members of the design team. Familiar nomenclature is used and the estimate is organized by components of the structure such as walls, partitions, furnishings, floors, ceilings, windows, doors, and special items. Special items include just about everything that cannot be described geometrically. At the present time the main user of the system is, of course, the cost estimating department. However, other departments are already making use of the quantity takeoff information currently available to them.

As I am sure you are aware, development of this system will be a continual process with logical breakpoints from time to time, and hopefully several years hence our system will dovetail into others and will make full use of graphical display devices and remote consoles of various types connected on-line to a central computer.

I want to thank at this time Mr. Charles Thomsen for inviting us to share with you some of the things which we are doing in Florida, and we have been very much impressed during the past year at what you gentlemen are doing in your own respective areas.

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