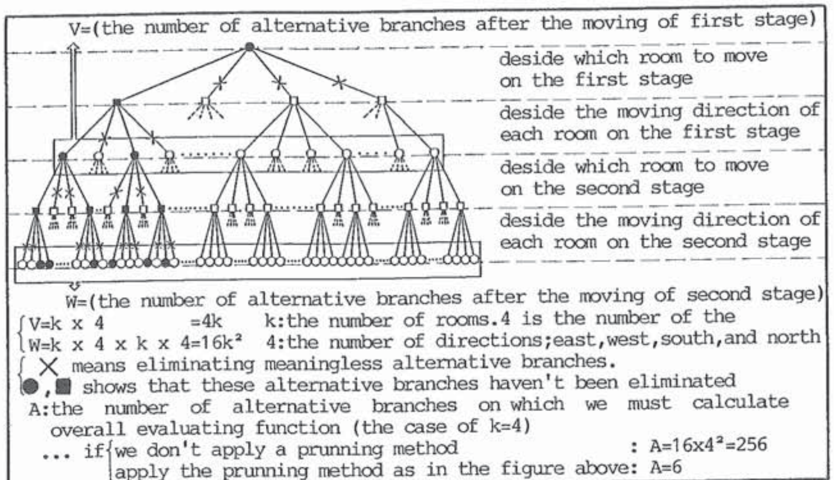

Fig.3 Explanation for a multi-stage searching and a prunning method (the case of four rooms)

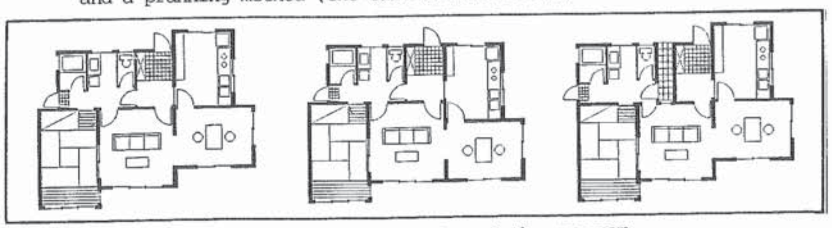

Fig.4 Examples of the results of execution of the program

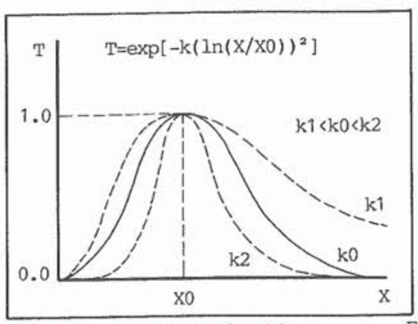

Fig.5 A membership function of flexible condition

Fig.6 Output plan by a model considering with a concept of flexible condition

Computer-aided design and its implications for the management of construction projects

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ABSTRACT

Many of today's computer-aided design (CAD) systems appear to be concerned with little more than the rapid production of drawings. This has given rise to a research project which is intended, amongst other things, to integrate time, cost and operational data into the working arrangements of a CAD system. By concentrating upon the needs of construction managers, it has been possible to examine the ways in which present generation CAD systems might be developed further to provide information for the management of construction projects. An overall structure for a CAD system, which is capable of providing this information, is proposed. It is based upon the structuring of an information-base which is manipulated by a relational data base management system (RDBMS) incorporating fourth generation programming language capabilities. In this way, a working system is possible which satisfies, not only the needs of the designer, but also those of the other members of the design/construction team. This should lead to greater certainty in design by providing more immediate feedback on time and cost.

Le design assisté par ordinateur et ses implications pour la direction des projets de construction

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SOMMAIRE

Actuellement la plupart des systèmes de 'design assisté par ordinateur' ('computer-aided design', CAD) ne semblent se concerner qu'avec la reproduction rapide des dessins. Cela a donné lieu à un projet de recherche visant, entre autres choses, à intégrer temps, coût et données opérationnelles dans les dispositions de travail d'un système CAD. En s'appliquant aux besoins du directeur de construction, il a été possible d'examiner par quels moyens il serait possible de développer la génération actuelle de systèmes CAD, afin d'en obtenir d'avantage d'informations nécessaires à la direction des projets de construction. Une structure globale pour un système CAD qui serait capable de fournir ces informations est proposée. Celle-ci est basée sur la structuration d'une base d'informations manipulée par un système de direction relationnel à la base de données ('relational data base management system', RDBMS), incorporant la possibilité d'utilisation des langages de programmation de quatrième génération. Ainsi il est possible d'arriver à un système de travail qui remplit non seulement les besoins du dessinateur, mais aussi ceux des autre membres de l'équipe de design/construction. En fournissant plus rapidement les données de temps et de coût, cela doit mener à une plus grande certitude dans le domaine du design.

1. INTRODUCTION

This paper examines the opportunities for the management of construction projects arising from the increasing use of CAD systems in the UK construction industry. The findings of thirty-eight case studies, as part of a Science and Engineering Research Council supported project [1], have confirmed the tendency for CAD systems to be identified, almost exclusively, with automating drawing production. Initial design work is more likely to be undertaken by hand, with the system used mainly for later detailed drawing production. In this scenario, the use of 2-D drafting systems dominates, with 3-D modelling systems more likely to be used as marketing aids. It is suggested that these practices overlook the possibility of CAD systems being used to integrate all design and construction data on a project. This could manifest itself in a design-oriented data base or equally, in a project-oriented data base.

2. CASE STUDIES

The decision to use a CAD system was often prompted by the award of a large project where standardisation and/or repetition were envisaged. This confirms that CAD systems were introduced primarily to automate drawing production. Furthermore, the high cost of these systems is blamed for the reluctance of users to depart from tried and tested methods. It was found that most organisations had undertaken trials and benchmark tests, geared mainly to measuring the speed of drafting and hence, savings in the cost of producing drawings. Once installed, the throughput of work needed to justify running costs sometimes meant that shift working and bureaux services had to be introduced.

The demands placed upon the computer's central processor normally meant that no other work could be accommodated. Serious degrading in response time was evident where any had been attempted. One effect of this was that specification and schedule editing was down-loaded to a word processor. Most CAD systems are equipped with data base facilities, although these were found to be under-used. It is recognised that introducing more data would be of immense help to disciplines other than the designer. However, this seems unlikely to happen until such time as there are sufficient financial incentives for the designer. The use of standard component libraries is virtually non-existent despite their being issued free of charge. They appear to have little to commend their widespread use until such time as all components can be selected from a library as easily as they might be selected now from trade literature etc..

Schedules and bills of materials were found to be by-products of many CAD systems. However, Bills of Quantities (BQ) production was a feature of very few systems and, where produced, were confined to a narrow range of standard building types. It is suggested that the prospects of a generalised CAD/BQ system being available in the near future are small. The problem rests with the way in which the design is created. Generally, for a design to be communicated from a CAD system to a BQ system, it would first need to be constructed in such a way as to make every measurable item identifiable.

A problem which designers face, when using component-based systems, is the creation of the components. It is often difficult to know where one is working within the component/sub-component relationship. Problems arise when different personnel are used to update drawings, as it is not always known how assemblies have been created. Agreement is required on the arrangement of components, their assemblies and communication standards, before data can be transferred successfully between systems, on a routine basis.

Generally, it was found that work in 2-D dominated with 3-D used mostly for visualisation purposes. However, experience has shown that once the system has been mastered by the user, 3-D geometric data input is no more difficult than 2-D input and far more useful to later evaluation exercises. Unfortunately, the mere provision of 3-D will not force a move away from practices instilled in the minds of the majority of designers.

The proliferation of microcomputer-based CAD systems is introducing many organisations to CAD techniques for the first time. However, expectations have tended to rise well above the actual performance of these systems, because many users are unaware of the limitations in them. Some of the important issues are discussed in the following Sections.

3. 2-D DRAFTING VS. 3-D MODELLING SYSTEMS.

A survey of microcomputer-based CAD systems, conducted as part of the research [1], found that 2-D drafting was the extent of most software packages. Many are little more than sketchpads with no knowledge of what the symbols mean nor the rules that might well govern the real world objects they represent. Most of the 2-D and 3-D systems surveyed allow a design to be created from discrete components, to which non-geometric attributes or properties can then be attached. These attributes usually allow bills of materials and other similar information to be generated. The implications of this are discussed shortly.

The issue of whether 2-D orthographic images or a 3-D model of the building is held in the computer is especially important. From a drafting point of view, there is a marked disadvantage in the simple 2-D approach. The different views of a building space (plan, elevation and section) or component assembly are unconnected and, therefore, a variation in one is not automatically made to the other(s). This represents a fundamental flaw in the 'electronic drafting' of a 3-D object such as a building. At one end of the communication's spectrum is a need to provide the client with an appreciation of the building's form and at the other end, there is a need to provide the building operative with component assembly details. It is imperative, therefore, that CAD systems for building design should be of the 3-D modelling variety to enable drawings to be produced on demand to suit individual needs.

A 3-D modelling system such as ACROPOLIS, running presently on minicomputers and stand alone workstations, offers a suitable approach to the 3-D modelling concept and highlights significant limitations in many of the microcomputer-based systems. The 3-D model is defined at the outset and all data, both geometric and non-geometric, are ascribed to it, rather than unconnected 2-D views. 2-D drafting systems that connect to other 3-D facilities (eg. AutoCAD and MegaCad) do not offer the same degree of model integration that would be expected with a true 3-D modelling system.

4. DATA BASE MANAGEMENT SYSTEMS

The extent to which CAD systems can be used to provide information, other than that expressed graphically, is limited by the amount of non-graphical data that can be handled. The degree of resource measurement that is possible is dependent upon the way these non-graphical data are related to the graphical data and then manipulated to produce schedules and reports. The hierarchical nature of most CAD data base management systems makes such manipulation difficult, because of their inherent lack of flexibility. The suitability of relational data bases, however, can be emphasised by their potential to maintain a single, coherent information-base representing all facets of a building. This information-base is defined currently by separate documents such as, drawings, specifications and bills of quantities, with each demanding different presentation requirements. Relational data base structures are especially suited to the needs of the design and construction team as they present data to the user in tabular form and allow subsequent changes to the data structures.

Building designs are detailed frequently using components from a data base. This component's data base has graphical and non-graphical (alphanumeric) sections, with the latter containing the attributes or properties of the components. In some systems, the attributes are restricted to a single word or code for each component; in others a large number of attributes can be attached to each component. However, data bases incorporated into many CAD systems are limited and a link to a more substantial data base management system may be required when the generation of non-graphical information is important.

The principle of the attribute system is the same for 2-D and 3-D software. However, there is a problem of consolidation with 2-D systems, because components are counted on every drawing and, therefore, may be included several times. 2-D systems calculate areas, but only 3-D systems can calculate volumes. Unfortunately, neither system can be guaranteed to produce accurate Bills of Quantities without much additional programming. For example, applied finishes are not normally detailed completely on all drawings, thus making their recognition extremely difficult.

Few relational data base management systems have been developed specifically for microcomputers, with the notable exceptions of dBase II/III. Many systems have been developed for mainframe computers, although ORACLE and RAPPORT have microcomputer versions running on IBM PC and certain compatible emulators. The main problems likely to be encountered with data base management systems on microcomputers are those of limited external storage capacity and available RAM. For instance, the drawings, attribute files and reports on one project could easily fill a 20 Mb hard disk. The limitations on memory size are even more restricting. Data base management systems can require as much memory as the CAD system and occasionally more.

There is little doubt that, at present, CAD systems on mainframes and minicomputers are capable of achieving significantly more than their microcomputer counterparts. However, this is true only of the limitations of microcomputers to facilitate 3-D modelling in a fast and presentable manner, and to process a range of non-geometric data concurrently. In particular, on-screen manipulation of 3-D models such as rotation, which is a prelude to animation, is virtually impossible to perform on microcomputers, because of limitations in processing and display technology. 3-D animation could provide a most valuable means of visualising the construction implications of a proposed design.

5. CADES (Computer-Aided Design and Evaluation System)

A system which is capable of expanding its function from drafting to the generation of information for construction estimating, planning and control purposes has been configured. The scheme of CADES, which is capable of generating both design and management information, is shown in Fig. 1. In its present form, it incorporates the 2-D and 3-D (wire-frame) versions of AutoCAD linked to ORACLE, a relational data base management system and is supported on an IBM PC AT microcomputer with 640 Kb RAM. AutoCAD incorporates an attribute facility which enables each component, or assembly of components, to be identified in a library of geometric entities. This provides the necessary identifiers to the information-base of non-geometric data held in tabular form within ORACLE. Such tables include data on costs, resources, outputs etc. which are related to components via the identifier. A particular feature of the system is the use of a bar chart (Gantt) as an input medium. This has been created to secure the rapid input of time-related data and is read by the system in the same way as any other geometric data. The various data can be incorporated in reports, of layout and content to suit the needs of individual users. Links to commercial construction management systems are being explored. These are likely to be achieved by producing the necessary interface programs using the fourth generation programming language capability of ORACLE.

A limitation in the above approach is that the construction sequence, as dictated by methods of working, cannot be handled automatically. The emergence of expert systems suggests a fruitful line of development. Indeed, Gray [2] has demonstrated that it is possible to embody the expert knowledge of the construction planner within a computer system and to apply it to design problems. The expert system incorporates a data base which contains the knowledge of several construction planners. This data base is manipulated by the inference engine written in PROLOG and designed to search the data base. An alternative approach might be to use a relational data base management system to provide the link between design elements, their construction definition and sequence within the construction process. This requires agreement on the structure of the data base that would be needed to capture the planned and actual timing of construction sequences. The intention of such an approach is to lead to the simulation of the construction process. This is considered in the next Section.

6. FUTURE DIRECTIONS

The case for examining construction sequences/methods of working is founded upon the belief that designs should be tested for 'good constructability' before construction commences. This approach is argued well by Griffith [3] who cites a number of factors which, if considered properly, will lead to 'better constructability'. These include the conceptualisation of the building process,

and construction sequences/methods of working, which are regarded as crucial factors for consideration by both designers and constructors. Griffith [4] has stated that "the actual construction sequence does not always follow a well defined flow of construction events as seen in bar chart and network diagrams. Thought must be generated towards developing more realistic and accurate forms of such representations..".

Cowan [5] identifies visual simulation as a growth area and describes a system where the user can construct and manipulate a complex model (mathematically, visually and interactively) to establish an optimum production plan. A feature of the system is that the user can override and modify the simulation should it prove undesirable. Such systems are becoming increasingly popular in manufacturing where production runs have to be planned precisely. Visual simulation makes this possible by permitting large numbers of iterations of the process to take place electronically in a relatively short time, without the cost of expensive mock-ups or interruptions to working plant and machinery.

Research [1] has found that visual simulation has made its mark upon the design process. In one case, a routine, similar to that used for N/C machine tools, was used to demonstrate how aircraft moved around runways and into hangers. From this it was possible to determine the most economic way of parking aircraft and positioning hangers. In another case, the movement of delivery vehicles across the site was superimposed to check for physical obstructions. It has been suggested by Atkin [6] that a similar approach could be applied to the major activities associated with the construction of a building. This would permit outline designs to be scrutinised closely by construction managers/planners prior to more detailed design commencing. Improvements within design practice are likely only if those data attributable to the construction process are incorporated into design principles. However, there are some practical limitations which must be considered. Firstly, it is unrealistic to expect the design to reflect every construction implication as some are unknown prior to work commencing on site. These construction data would include details of temporary works, plant and machinery, storage etc. and, although rarely associated with the final built form, are a significant proportion of the total cost of a project. Secondly, the handling of construction data, by a computer, is not inherently different from that of component data. Some of the features of a CAD system, namely overlay, clash and consistency checking etc. could be applied to these data once incorporated within the system. A prerequisite of this approach would be to formalise the construction planner's thinking in terms of the locations, sequencing and timing for all construction data.

7. CONCLUSIONS

The findings of the research confirm the view that the industry is content with automating traditional practices; that many CAD systems have the potential to integrate information for the management of construction projects; and that the data base management system is at the heart of the full (integrated) system. The use of 3-D modelling systems is vital to exploiting CAD technology fully and to providing the mechanism for linking to systems for estimating, planning and controlling the construction process. However, the responsibility for incorporating the necessary data into the system cannot fall to the designer, when there is no obvious financial gain. In the absence of such consideration, the outcome is an increasing development of interest within construction management. As more organisations recognise the benefits of employing CAD systems, the overlap in the services which they offer to clients will continue to erode long standing professional barriers. This is likely to accelerate as technology and cost move within the reach of an increasing proportion of the construction industry.

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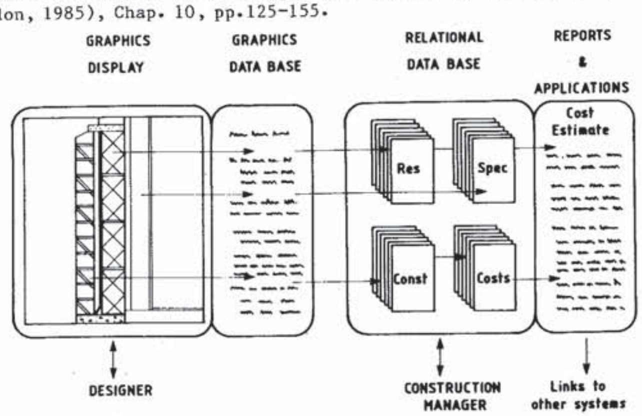

FIG. 1: SCHEME OF COMPUTER-AIDED DESIGN AND EVALUATION SYSTEM

Mathematical Modelling and Electronic Computing Machinery in Town Planning

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Urban Design, Computer-Aided Design, Program Pack, Mathematical Model, Information Provision.

ABSTRACT

The report deals with the main applications of mathematical methods and electronic computing machinery for the town planning needs with a view to: organize the information retrieval systems and data banks; undertake labour-intensive calculations; prepare the project documentation and model the design objects performance in order to evaluate the planning decisions. There follows the basic principles of the mathematical models used to solve the town planning problems including analysis of the land use and land-use zoning, analysis and evaluation of urban planning patterns, location of public service facilities, transportation planning, environmental quality evaluation, etc. The report contains information on the mathematical models implemented in the applied program packs, peculiarities of their use in conventional design, results and efficiency of their use. The concept is discussed of a technological line for the computer-aided development of the town master plan based on a wide use of mathematical modelling, computer-aided means to undertake the labour-intensive calculations and to prepare the project documentation. Also discussed are the possibilities and prospects of the computer-aided urban design.