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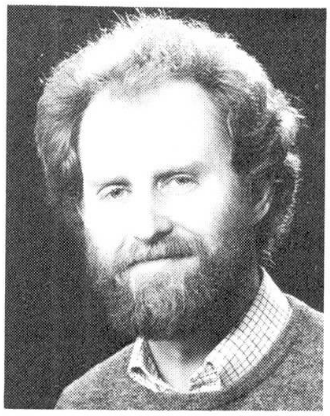
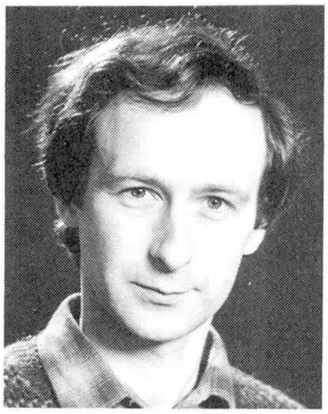
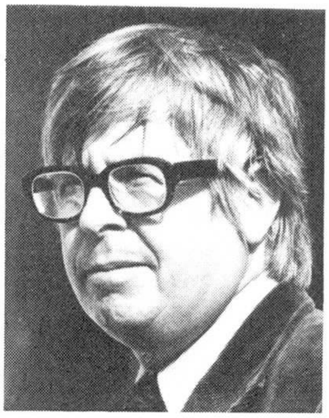
Computers and the Organisation of Design

Ordinateur et organisation du projet

Computer und die Organisation des Entwurfsprozesses







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SUMMARY
Case study material has been collected on UK building projects where there has been significant use of new technology. It appears that although improved ways of communicating project information are now technically possible these opportunities are rarely grasped. Instead CAD and other systems are used to automate routine internal functions and project communications are handled in traditional ways. The relationship between new technology and existing organisational systems is considered in the light of these findings.

RÉSUMÉ
Des données ont été collectées sur des projets de construction en Grande-Bretagne dans lesquels l'emploi de nouvelles technologies est considérable. Malgré l'amélioration des moyens de communication, les informations sur les projets sont rarement échangées. La conception assistée par ordinateur et d'autres systèmes sont appliqués pour automatiser les fonctions internes habituelles et la communication se poursuit selon des méthodes traditionnelles. Le rapport entre la nouvelle technologie et les systèmes d'organisation actuels est examiné sur la base de cette situation.

ZUSAMMENFASSUNG
In einer breit angelegten Studie wurde Material über die praktische Anwendung von Computern in englischen Projektierungsbüros gesammelt. Die Auswertung zeigt, dass trotz rascher Entwicklung der Computertechnik, dieses Hilfsmittel hauptsächlich für die Rationalisierung von betriebsinternen Abläufen, z.B. CAD verwendet wird, und heute noch wenig für den Informationsaustausch zwischen den Büros eingesetzt wird. Aufgrund dieser Erkenntnisse wird der Zusammenhang zwischen den bestehenden Organisationsformen und den neuen EDV-Technologien untersucht.

1. INTRODUCTION

The activity of building is a complex one, necessitating many different skills and a variety of organisations. Anything which can help to improve the whole process of design and construction is to be welcomed and many in the industry see the computer in this role. Considerable hopes are being invested in the increased development and utilisation of computer aided design and draughting technology (CAD) as a way of streamlining the building industry and improving performance.

In terms of the design professions involved in construction (architects, engineers, quantity surveyors) computer systems are being introduced at two distinct levels. Firstly there is the <u>in-house system</u> which is purchased by a single organisation as a way of automating its internal functions. A good example would be a CAD system purchased by an architectural practice for use on a variety of jobs. The system may have considerable effects on the workings of the practice, and indeed these effects will probably be felt by external organisations, but the product of the practice in terms of drawings and specifications will be wholly traditional. The drawings may be clearer and the specification more comprehensive but they will be handed over to the other consultants and the contractor in exactly the same way as if they had been produced manually. At present this is by far the most common level of computerisation in the UK building industry.

However many commentators are anticipating a second level of computerisation where the benefits of the new technology will be exploited to the full. The <u>project system</u> is one where all the members of the design and construction team on a particular building project will have access to a common computer system, or a series of fully compatible systems, where design information is exchanged electronically. Data generated by one member of the design team will be instantly available to all others, and on the most sophisticated systems everybody will be working on a common three-dimensional model of the building and will therefore always have access to the most up to date information. It is hoped that many of the current problems of communication will disappear and the whole process of building will be managed more efficiently and economically. This view of the future is one that is promoted by the computer industry and assumes that the availability of a particular technology will result directly in changes to organisational systems. Although in some instances this may happen it is not necessarily the case and this paper will argue that it is often more useful to look at organisations and technology as being mutually interdependent rather than one having a direct and unmediated effect on the other.

In the case of computers and the building industry there are many individuals with personal experience of new technology who have strongly held views. However there is little in the way of systematic evidence on how the existing computer-based systems are being introduced and used. The present paper is intended to go some way towards filling that gap. Over the past 18 months researchers at the University of Bath have been carrying out a series of case studies on live building projects in the United Kingdom where there has been significant use of new technology. These case studies provide information on how the existing technology is being introduced and used in traditional design and contracting organisations. In all cases the systems used were of the in-house type although anecdotal evidence was collected on situations where there had been electronic data transfer. From the information collected it is clear that even existing technical opportunities for inter-professional working are not being grasped and that the future of project based systems will undoubtedly be profoundly affected by social as well as technological constraints.

2. THE CASE STUDIES

To date case studies of five live building projects have been completed and interviews with all members of the building team, including clients and contractors, carried out. The projects were selected through a list of design practices in the UK who, at the time, were significant computer users. Most operated some kind of minicomputer-based computer-aided design and draughting system. A selection of practices were contacted and those who agreed to take part in the study were asked to nominate a current building project which was fairly representative in terms of computer use, and which was between tender stage and completion.

In all cases representatives from the architect's, the structural engineer's, the services engineer's, the quantity surveyor's, the contractor's and the client's organisation were interviewed on the communication processes between the various parties. Information was also sought on the way in which computers had been introduced and were being used within the organisations studied.

The case studies were confined to the private sector; all the projects were for single buildings of a value between £2M and £13M, using traditional forms of design organisation. What follows is a summary of some of the points which emerged from the case study material. In most cases each point was raised more than once and is therefore not unique to a particular project or individual. It must be remembered that these issues reflect the respondent's <u>experience</u> of using computer systems and not how they should be used in an ideal world.

3. IN-HOUSE COMPUTER SYSTEMS

Since the design process normally starts in the architect's office it is appropriate to see how computers are used there. It is around the nucleus of design information that improvements in inter-professional communication are expected to be seen.

3.1 The Use of Computers at the Design Stage

Although the sales literature for CAD systems often highlights the way in which computers will help the designer in developing his initial ideas, the case studies produced no evidence to indicate that this is the way the systems are used in practice. Perhaps one reason for this has to do with the differences between how an architect traditionally works and the way in which he has to work when using a CAD system. Normally when an architect starts on the design of a building he moves from the general to the particular. That is to say he produces an original idea which is developed by testing it against the brief. The building is worked up from rough drawings, through a series of 'sketch plans', to a final set of working drawings which are used for construction. Although the architect may have some idea of how he is going to construct the building when he is at sketch plan stage, he will probably not have thought about the details in other than the most general terms. His concerns at the early design stage are for the general planning of the building, the relationship of the various spaces one to another, and the external appearance of the building. Using a traditional drawing board and T-square he will be able to produce a complete set of plans, sections and elevations at at scale of 1:200 or 1:100 sufficient to explain the scheme to his client, or to obtain detailed planning permission.

If he tries to produce such a set of drawings using the kind of CAD system used in the case studies he comes up against certain problems. The computer works with a 1:1 scale model of the building in its memory. The operator therefore requires detailed information on parts of the building, such as windows or columns, as he is entering data. In fact the computer works best starting from the detail and working up to the whole. That is exactly the reverse of the traditional approach and it is one factor which makes it difficult for architects to use the computer for the initial stages of the design work.

In none of the case studies was the computer used for 'design'. It was always used for producing general arrangement drawings at a scale between 1:200 and 1:20 during the working drawing phase. In most cases the sketch plans for client approval and the drawings for planning permission were produced manually. In one office, where the computer operator was a technician with no design authority, the architect in charge of the job had to resort to instructing him to 'fudge' the information in order to allow the architect to continue working in his usual way. Another respondent, who was particularly committed to the use of computers, commented that in order to use the computer for all stages of the work he had had to revise his working methods. He always thought about details as he was designing the building, and accepted that one had to work to a much more rigorous timetable if the computer was to be used effectively during all stages of a job.

One thing that emerged from all the case studies is that the use of computer-aided design and draughting systems is concentrated very heavily in one stage of the design process. Despite the claims of the manufacturers and suppliers, CAD systems do not seem to be used to any significant extent in the early 'creative' design stages. They are used as automated technicians to churn out general arrangment and working drawings at scales of up to 1:20. Occasionally they are used to produce base drawings for client presentation, but these are often finished off by hand, even though they may be presented to a client as 'computer-produced'.

3.2 Standardisation of Project Information

There is undoubtedly resistance to some working practices promoted as optimal uses of the machine. One rather surprising finding which emerged was how little CAD systems seem to be used for producing standard details in architects' offices. During the interviews non-users often commented that they felt that one of the most appropriate uses for a CAD system would be for it to hold a library of tried and tested standard details which could be used on a variety of jobs. In practice we found that this hardly ever happened, although in one architectural office there had been a considerable investment creating such a library. When it came to using the library it was found that architects preferred to work out their own details for a job rather than resorting to those already available. There seems to be less reluctance to use a library of manufacturers' components such as plans, sections and elevations of sanitary ware or contract furniture. One explanation might be that the details can be seen as relating to the design function whereas the components merely ease the draughting process. For an architect the design decision is in their selection and location, not in their creation. This attitude is in direct contrast to engineering practices with their tradition of industry-wide standard details.

Similarly, the temptation to use standard, industry-wide specifications in word-processor based systems is over-ridden by the desire to produce specifications particularly suited to individual practices. This appeared to be part of a general concern relating to each practice developing and promoting its own unique image.

3.3 The Organisation of In-house CAD Systems

When a CAD system is introduced into an architect's office there is usually a fairly senior member of staff who has acted as 'promoter' and has spent a considerable amount of time selecting the system and negotiating with manufacturers and suppliers. Decisions have to be made about who is to be trained in its use and in the office there will probably be a split between those (usually younger) who are keen to 'have a go', and those (often older) who would rather carry on as before. In most cases the CAD system will have been bought with only one or two work stations and even when fully operational will only cope with about 20% of the total office workload. There is therefore a choice available regarding those who will be trained. It is often surprising to the outsider that even in an office which appears to be fully computerised most of the drawing is still carried out manually.

Initially most offices encourage widespread involvement with the system, and it tends to be thought of as a resource, like a photocopier, which can be used by anyone, virtually at any time. However, as experience is gained it becomes clear that this is not really feasible as the computer (unlike the photocopier) is an expensive and therefore a scarce resource. Once a particular job is committed to the computer it is infuriating to find that the system is tied up by somebody else doing what appears to be a relatively trivial task. So either the computer is dedicated to a single, usually large, job or a management system develops involving booking sheets, priority schedules and sometimes shift working. In medium to large size practices a computer manager either grows up from within the organisation or is employed specifically to run the system at peak efficiency. The working day is typically extended to two or three shifts from, perhaps, 8am to 6 or 8pm. Similarly, specialist computer operators tend to emerge and as their skills develop it is increasingly inefficient for others to use the machine. Many offices, despite an initial reluctance, find that the most practical solution is to set up an in-house computer bureau. The computer facilities are then concentrated in one location and manned by a specialist group who are 'hired out' to specific project teams.

One issue which emerged in the case studies which is of interest in this context concerns the sporadic use of the CAD system in the design office. We were told on a number of occasions of jobs that were taken off the computer for a variety of reasons. Sometimes it was a result of problems with booking the system, sometimes because of a system failure, or even because of frustration with how poorly the system was performing. If an attempt was made to re-introduce the computer after a period of manual working a great deal of additional work was generated trying to reconcile the computer model with the detailed changes which had occurred during the intervening period. In some cases this seems to have led to considerable frustration and disillusionment with the system as a whole. The conclusion to be drawn is that the use of manual plus computer-aided methods for producing the same type of design information on the same project is very likely to cause extra problems of co-ordination.

The introduction of a CAD system can therefore have a considerable effect on decisions regarding the way in which an office is managed. New roles can be created within the office and a new organisation of discipline emerges; one that is partly based on the perceived demands of the computer rather than of the individual projects which are being designed. The introduction of such systems can therefore contribute to increased fragmentation of roles and an increase in the specialisation of functions in the organisation. The very fact that a computer is to be purchased can be a spur to re-thinking the management philosophy within an office. Indeed the precipitating factor when considering such an investment might not be the explicit benefits of computerisation, but the opportunities presented for a 'fresh start' in management terms.

3.4 Co-ordination and Control

Computer systems of all kinds are promoted on the basis that they provide opportunities to improve the control over a particular process. Some, such as the critical path analyses used on construction sites, have this as their primary task while for others, like CAD systems, it is a secondary benefit. In an architect's office where all the drawing work is carried out manually a medium-sized building might require the efforts of a senior architect on a part-time basis, a job architect full time and, say, four or five technicians. The work of all these people has to be co-ordinated if the job is going to be relatively trouble free. If a CAD system is used the same job could be handled with only one or two technicians and the task of co-ordination becomes much simpler. Also, because the computer is working on a model of the building, rather than on a series of separate drawings, a much higher standard of internal consistency is achieved on the drawings produced. On the other hand managements may create further specialised roles in association with the introduction of a CAD system, and this can increase the complexity of the staff management process.

A by-product of using a CAD system is that management information can be generated on the efficiency of the system as a whole. The operating system typically records the amount of time each operator has been logged onto the machine, and it is a simple matter to count how many commands were entered during a particular session. It it can therefore be much easier to monitor the costs of a particular job to the office, and also to gauge the efficiency of a particular employee.

3.5 In-house Computers in Contracting Organisations

Turning to applications in contracting, in several case studies, a national contracting organisation with local offices used a central mainframe computer to control costs on building projects. A budget was set up for each job in head office and then information collected from the sites on the progress of the works, on the materials used and on the wages paid to the operatives. This was then collated into a monthly statement and issued to those in management positions in head office, in the regional office and on site. This level of control is much greater than achieved previously and allows problems to be identified earlier, and with more precision. Even the construction manager, who is involved with the project on a day to day basis, has more information than in the past. However, from his point of view, there is also a penalty to be paid with the decrease of individual discretion. Before the introduction of the computerised project management system the construction manager had a less clear, but in his opinion quite adequate, picture of what was going on in a particular project. He knew that they were probably overspending in one area but hoped to recoup the loss with a saving elsewhere. His objection to the new system is not that it produces more accurate and detailed information, but that information is now available to everyone and he no longer has as much discretion to run the project in his own way and take responsibility for it at the end of the day. His 'span of responsibility' has been considerably reduced.

4. COMMUNICATION OF COMPUTER-BASED INFORMATION BETWEEN ORGANISATIONS

Although in none of the case studies was there a fully linked computer system in operation an examination of the communications processes between the various organisations was carried out. In particular there was an attempt to assess the effects of the use of in-house computer systems on the project as a whole.

4.1 Computer-aided Draughting Systems

One great advantage of any electronic typing or draughting system is that the operations involved in the creation of the work are separated from its actual production. Thus the typist can create a letter on a word processor, edit it and amend it in various ways, all prior to its printing. The printing process is relatively quick and should not even require supervision. If the letter has to be further amended, printing another version involves very little additional work. The process is very similar with a computer-aided draughting system, although the timescale is rather extended. The production of a detailed working drawing might take a technician a week or longer using manual techniques. Creating the same drawing using a computer will take a similar amount of time, but the great advantages of a CAD system are that the drawing can be amended very easily, can be plotted at a number of different scales, and can be made up of several 'layers' each of which can be plotted separately. As with the word processor the drawing time is relatively quick and a modern electrostatic plotter can produce a detailed, high quality A0 drawing in several minutes.

When a design team is working on a project there is usually a project timetable drawn up which sets out dates by which the various members have to produce specific pieces of information. Because a whole set of drawings can be plotted relatively quickly, there is a tendency to leave the plotting until immediately before the due date for the information, in order to ensure that all amendments are incorporated. Such a policy is followed in order to ensure, as far as is possible, an accurate and internally consistent set of drawings, but it does have other consequences.

In an office where drawings are being produced manually they exist physically at all stages in the process. Thus a print can be run off at any time and sent to another consultant who can use it to co-ordinate his work. With an electronic system any specific drawing only exists as a potential drawing until it is plotted. Thus if drawn information is to be sent to another consultant the particular drawing must be selected, plotted and then printed. Although the difference between the two systems seems to be fairly marginal, it appears that where there is the potential to issue a 'perfect' drawing there is a much greater reluctance to issue <u>any</u> drawing until that perfect drawing is available. Thus the information flow, as far as drawings are concerned, tends to focus much more around the timetabled dates, and there is less exchange of informal information during the intervening periods. In fact one structural engineer believed that the architects' use of CAD actually resulted in a greater requirement for informal communications for clarification purposes, when a set of drawings eventually reached him.

This has an effect on consultants, particularly the engineers and QSs, who are working with architects using CAD systems. They report that there is a tendency for the information to be 'bunched' much more than when traditional techniques are being used. They receive relatively little information for a period and then a whole set of immaculately produced drawings arrive, which they can find difficult to digest. When the drawings are being produced manually more information is received in 'sketch' form and this allows the consultants both to assimilate the building and also to begin to develop their own design strategies. However, although this may have a clustering effect on project information flow, several interviewees (engineers and QSs) commented that it was not a problem for them as it allowed them to concentrate resources on other pressing work during the slack periods.

Perceived delays in communicating design decisions appeared to be related to the complexity of the organisation of the architect's team, as well as client-related factors. The in-house benefits of CAD are thus dependent upon organisational and other factors if they are to result in benefits of speed at the level of project communications. The greater the differentiation of roles between design and contract functions, and between responsibility for graphic (drawing) and related text (specification) information, then the greater was the likelihood that this complexity would be seen as a source of delay in decision-making by other members of the team.

4.2 The Quality of Computer Produced Drawings

The quality of computer-aided design information was generally regarded as good by other building team members. The typical attitude was that as long as the information was accurate its method of production was irrelevant.

One contractor believed that the computer was inflexible in some of its technical capabilities and that this had delayed his programme. In particular he gave the example of the difficulty the system had in creating holes in floor grids for the accommodation of structural members, especially when they were not all regularly spaced. A structural engineer believed that, generally, computer-aided drawings looked bland, and could be difficult to read because of the relative lack of difference between different weights of line, e.g. dimension lines and outlines on layout drawings. Otherwise, although the late arrival of design information was noted fairly frequently, it was acknowledged that reasons extraneous to the draughting system itself were responsible (such as site starts being required very soon after letting of the main contract).

4.3 Word-processing of Specification Information

Many of the design offices contacted in the study produced specifications using word processors. These were typically operated either by a specialised individual operator or, in large practices, by a separate division dedicated to the provision of technical information in text form. Communication of this information at project level was in the traditional form of a document and team members in receipt of this information made a number of comments. Unsurprisingly, these came predominantly from those most dependent upon the quality of information about materials, namely contractors and quantity surveyors.

Comments concerned both the content and presentation of the information. A construction manager found difficulties both with the sheer volume of word-processor based specifications, and attributed a number of conflicting clauses to the psychological credibility of the computer printout. He believed that the word-processor operator did not fully check the specification because the neat and clean appearance of the output made it look as if there could not possibly be any mistakes. Similar points were made by quantity surveyors, who also noted shortcomings in the indexing of specifications. This appeared to be a teething problem in the application of the word-processing systems, of which the users were aware, and which they were in the process of improving.

4.4 Work Programming Information

In all the case studies Contractors used computers to some extent to produce work programming information. This took the form either of on-site microcomputers or the application of standard software packages on office-based mainframes. Direct site-to-office links were not encountered in the case studies. The applications used the standard critical path and network analysis techniques. Printout took the form either of precedence networks or bar charts.

The output programming information had a number of intended and unintended consequences. Construction managers or site agents and other members of the building team found the programmes useful, but in a variety of ways. Members of the design team were guided by the programmes in the conventional manner, but the format could be problematic. In one project on a very tight schedule, other members of the team found the programme very difficult to 'read' because of its sheer length. This was caused by the inputting of arrow diagrams, a method which meant, for example, that a 30-week activity could be split into 15 two-week blocks all with the same name and all appearing in different places in the printout. This method was abandoned during the project and replaced by a line of precedence method, producing an output more like the conventional bar-chart. On another project where programming had been by manual methods, the need to produce an accelerated completion programme resulted in the contractors' central planning resources being called upon, and the HQ Planning Department produced a complex programme using their mainframe based software. The construction manager found this unusable for any practical purpose, containing far too many separate work elements. In fact, this programme, displayed on the wall of the site meeting room, was widely regarded as a work of art in itself. The construction manager acknowledged that its main purpose was probably to maintain a credible image in the eyes of the client. He continued producing his own manual bar-charts for the practical programming of the work.

Another site agent regarded the purpose of such computer-aided programmes as being merely to act as reminders in a situation where the priorities were well known anyway.

The above examples illustrate an important point: computer technology and its products are involved in the social complexities of communication processes no less than any other technical resource. A programme intended as a practical aid to work planning becomes a form of symbolic communication as part of an effort to create an image for clients; a site agent regards a programme not as a guide in itself but as an aide-memoire, and so on. The unintended consequences of the application of new technology are thus as important as the intended consequences.

4.5 Inter-professional Working Using In-house Systems

Promoters of CAD systems point out that once data about a particular design are entered into a computer the information can be manipulated in a number of ways. It can be used to produce drawings of the whole building or of parts of the building to a variety of scales. It can also be used to calculate areas, to count the number of particular components, or to produce schedules of one kind or another. A quantity surveyor can use the system to save a great deal of boring and repetitive work in calculating building costs through a detailed analysis of areas, quantities of materials and labour rates for particular jobs. Several software packages are available which would substantially reduce the task of the QS in producing bills of quantities.

In practice these opportunities for inter-professional working have not been be grasped. On all the jobs we studied the communication process between the various consultants was carried out in wholly traditional ways. The architect would use his CAD system to produce a set of working drawings, plot them, and then print them as with manual drawings, and hand the prints over to the other members of the design team. The QS would then take these prints and, if using a computer-based system, he would digitise them in order to get the data into his machine and so start producing costing information. Alternatively, and this proved to be much more common, the QS would use the computer-produced drawings to take-off quantities using a scale rule and pocket calculator. Only if there was a particularly complex geometric shape would he go back to the architect and ask him to use the computer to calculate that particular area.

One architect's office actually had software mounted on its computer to produce a bill of quantities with little additional effort, once the architectural data were entered. When asked why this facility was never used we were told that its use would upset their relationship with various quantity surveying practices who were useful sources of future work.

We did find two examples where the electronic transfer of data had occurred. In one a land surveyor had provided an architect with digitised site plans, and in the other a highway engineer had used an architect's CAD system to help him calculate the complex geometry involved in the setting out of roads on a small housing estate. However these examples were the exception rather than the rule and were not drawn directly from the case study projects. They were given by respondents as examples of other projects where the computer system had been used across professional boundaries.

There are several reasons why computers do not currently seem to be being used in this way. Clearly a major factor is the technical incompatibility of existing computer systems. In traditional practice one is working on a series of discrete projects, often with a variety of other consultants and contractors. Even if more than one party has a CAD system it is very improbable that a direct exchange of information would be possible. The computer industry is highly fragmented and there is a tendency for manufacturers to encourage brand loyalty through product exclusivity. If compatibility is a high priority then it becomes something that must be considered when a system is being purchased and this places major restrictions on choice. Although there are instances where individual architectural and engineering practices have decided to buy fully compatible systems, or indeed to share a single system (1), these are relatively rare. Also having made the decision to invest in this way means that the practices must commit themselves to working together and there then emerges a grouping that lies halfway between traditional practice and multi-disciplinary working. There are various attempts to overcome the technical problem of compatibility through intermediate 'translation' equipment, but progress is relatively slow and the product hungry in terms of processing power.

Another reason has to do with the maintenance of clear professional boundaries and areas of experise, even if these are cut across by the technical capacities of the computer system. If one member of the design team uses his CAD system to do something that would normally be considered the province of a colleague it has to be paid for in some way. If the effort involved on the part of the CAD user is relatively low but the benefit gained elsewhere is high, how does one arrive at a fair cost for the work? Also it is not advantageous to any professional to reduce his involvement in a project by passing work, responsibilities and fees into the hands of another.

Other problems can arise in this sensitive area of inter-professional boundaries. For example, professional liability insurers may repudiate any claim made against someone, on the grounds that by doing a particular piece of work he is stepping beyond his qualifications and experience.

5. CONCLUSIONS

The information reported in this paper concerns itself with the ways in which in-house computer systems are being used on traditionally organised building projects. As far as CAD systems are concerned their main use is to produce sets of layout and working drawings at scales of up to 1:20. These drawings are often complemented by specifications produced on word-processors operating independently of the CAD system. There is little evidence of computers being used during the early architectural design stages.

Computer systems are being used, in the main, to automate internal processes within specific organisations. Although respondents talked of the possibility of communicating information electronically there were few examples of this in practice. Similarly there seemed to be a reluctance for professionals to 'poach' in one another's area of expertise, even though this was technically possible.

In all it seems that although considerable benefits are being realised through the use of computers there are further benefits which are currently not being felt because of the problems of working and communicating across professional boundaries. Some of these problems are purely technical but the majority have to do with the inter-relationship between the technology, the organisational systems, the professional interests and the managerial goals currently evident within the industry. The present system of project working has developed historically and has been reinforced over the past hundred years by the formation of professional institutions with jealously guarded areas of expertise and influence. The traditional building project necessitates a number of different organisations, each with its own professional or technical skills, coming together in a temporary coalition in order to provide the client with a building. Each organisation has its own professional ties and internal goals which it brings with it, and these affect project performance. By and large there is a mutuality of interest in maintaining clear boundaries between these various organisations, and transactions across the boundaries take on special significance.

Anything which blurs these boundary transactions, such as electronic data transfer, or simultaneous working on the same computer model of the building, is disquieting. Either relationships have to renegotiated, which can be traumatic, or there is a fall-back to previously existing patterns.

However the existing situation also has certain benefits. In an industry where there is often considerable pressure to perform quickly and efficiently there are advantages for the individual in having a fragmented project organisation. Blame and responsibility are difficult to allocate and there is considerable scope for the separate organisations to maintain their own self image and prestige at the expense of others. (2)

The development and implementation of computers is not the only agent for change in today's building industry. There are pressures, many client-induced (3), for new forms of project management and the various professions are vying with one another to place themselves in the driving seat. Increasingly contractors are offering package deals, or a full design-build service, either using in-house professionals or by entering into agreements with specific outside practices. Multi-disciplinary practices encompass all the professionals within one organisation and offer an integrated approach to building design.

Package deals, design build, and multi-disciplinary practice all appear better equipped to make fuller use of the new technology than traditional practice. As they are in control of a greater proportion of the whole process they are not so bedevilled by problems of compatibility. The boundary transactions are less formal and thus more amenable to the influences of new technology. That is not to say that traditional practice, like a victim of natural selection, is doomed as the benefits of the computer are increasingly felt. Rather the point to be made is that computerisation can not be viewed as an inevitable process which is determined only by technical developments. The potential of the new technology is mediated both by the organisational structure into which it is introduced and by managerial goals in its application. (4) In some cases an existing inappropriate structure, or particular occupational interests will be so powerful and so deeply embedded that the introduction of new technology will be subverted and the result will be worse than useless. In others the organisational structure will adapt or will be consciously changed to meet the new needs. And in some the existing structure will be well suited to the needs of the new technology and the uptake of computers will be simpler, with more possibility of it being used at nearer full potential.

At the present time many in the building industry are considering how best to introduce the current generation of computers into their organisations. The decisions relating to the hardware and software are difficult enough, given the way in which computers are developed and marketed. The glittering array of products and the competing claims of rival sales teams are enough to confuse even the most dedicated customer. But it must be remembered that all that is only one part of the equation. The organisational aspects of the investment, both in terms of in-house working and project organisation, must be thought through in parallel with the technical issues. The two are so intertwined that to consider one without the other is, to say the least, naive.

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