PART I

IT and *Praxis*

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This is a report on the dynamic relationship between information technology (IT) and architectural practice. The report summarises the attitudes and opinions of practitioners gathered through extensive recorded interviews, and compares these attitudes and opinions with the findings of other studies. The report is compiled from the point of view of an understanding of *praxis*-appropriating *practice* as preceding *theory* as the model for understanding. We thereby connect what is going on in IT with concepts currently under discussion in postmodern thought and in the tradition of philosophical pragmatism. We identify several of the major options identified by practitioners in their use of IT, including practicing without computers, substituting computers for traditional tasks, delivering traditional services in an innovative way through IT, and developing new services with IT. We also demonstrate how firms are changing and are being shaped by the market for architectural services. One of the major areas of change is in how IT and related resources are managed. We also consider how the role of the practitioner as an individual in a firm is changing along with changes in IT, and how different prognoses about the future of IT in practice are influenced by certain dominant metaphors. Our conclusion is that IT is best understood and appropriated when it is seen as fitting into a dynamic field or constellation of technologies and practices. Such an orientation enables the reflective practitioner to confront what is really going on as IT interacts with practice.

Information technology (IT) includes computers, such as graphics workstations and desktop and portable computers, communications tools such as telephones, cellular phones and faxes, and peripherals such as file servers, printers, plotters, digitisers, scanners and slide writers. It also includes databases, CAD systems, wordprocessors, electronic communications systems, multimedia and other data and programs. Information technology has introduced new dynamics into architectural and engineering practice. The influence of a technology is commonly seen in terms of *impact*, as though the technology is an isolated phenomenon that makes some particular operation more or less efficient. In this study we attempt to move beyond the concept of *impact* to address the complexities of IT in practice.

This study focuses on an interview survey of design practitioners that revealed certain practices, allegiances, tensions and contradictions about IT use. There appear to be two conflicting views presented by practitioners. One is to conceive of the impact of technology in *theoretical* terms, with reference to rigidly defined rationales, the expectation that things should conform to the dictates of logic, and that IT is provided to address well-defined problems. In tension with this view there is the *pragmatic* view-a recognition of the importance of *praxis*, of everyday socially situated practices in shaping the way information technology is adopted. The theoretical view masks the plurality of ways in which IT is taken up. In following the pragmatic

strand within the survey responses we discovered that practitioners were adopting IT in four ways: (i) some were substituting automated tasks for traditional tasks, (ii) others were delivering traditional services in innovative ways made possible through the use of IT, and (iii) others were developing extended IT-based services. Furthermore, statistics from other surveys indicate (iv) that many architectural practices continue to operate without advanced IT such as computers.

Our survey also revealed that important trends are emerging as to how practitioners regard their market in an IT context. The attitudes of practitioners towards IT reflect existing divisions within the profession as to the role of the architect. Furthermore, a new IT based definition of the architect is emerging: the architect *as* a generator and coordinator of information.

Our interviews with practitioners revealed a number of contradictory opinions on the impact of IT on the day to day tasks of the architect. Practitioners are divided on the issue of whether the introduction of IT leads to deskilling or reskilling; on the role that technology plays in relation to design activity; and on whether IT facilitates autonomy, is an essentially isolating phenomenon, or reinforces the interdependence of a matrix of practices and players. With regard to management issues raised by IT, new practices are emerging around the issues of day to day management, IT selection, training and customisation.

Finally, the prognosis for the future of IT in practice is defined in terms of certain technical problems seen through a range of "metaphorical orientations." Where the computer is understood as a set of disparate technologies, technical issues are defined in terms of the quest for total integration and centralised comprehensive databases. A further metaphor is that of the computer as intelligent system, in which case the future lies in the codification of human expertise to make computer systems more effective. Where the computer is seen as a communications device, then the challenge is to develop systems that enable practitioners to exchange information and to collaborate. Where the computer is understood as a mass media technology then the challenge is how best to promote the firm with IT, and how to integrate video presentations, audio visuals and computerised multimedia.

This study is of relevance to practitioners in several ways. First, for those who already make use of computing we open up new ways of looking at that technology by drawing attention to assumptions at work. Second, for those practitioners still contemplating the move into advanced information technology we aim to convey a realistic sense of the state of play. Third, the study is also of relevance to those who supply the technology and technology based services: researchers, developers, consultants and vendors. One of the difficulties that has emerged in the field is a lack of appreciation by such "suppliers" of the way that practitioners actually work. This study presents opinions and attitudes evident amongst practitioners. These practitioners are from a range of backgrounds and have a diversity of technical expertise. The emphasis of this study is on elucidating the often hard won insights of these practitioners into the relevance, benefits, pitfalls, and techniques of information technology applied to their practices and their profession.

Unless otherwise indicated all quotations in this article are from interview respondents.

Models for exploring the implications of IT

There are a number of models of how organisations operate. These models impinge on how people understand technology. First, there is the *rational decision making* model of organisations. Here the emphasis is on detached principled decision making. Technology is regarded as a variable in a matrix of variables to be taken into account in making "rational" decisions about the future. Rational decision making does not rule out the possibility of other kinds of decision making (such as *intuitive* decision making), but it seeks to be clear about the distinction and the priority of each. Second, there is the model of *technological determinism*, of technology as determining the changes that confront practice (Forrester, 1989). Technology is regarded as a prime cause above anything else-social factors, work practices, etc. These two models seem to be privileged in technical and managerial theory, though not necessarily amongst practitioners

themselves. Third, there is the *praxis* model in which technology is regarded instrumentally as equipment that we use to get things done in some specific work context. The emphasis is on human action in a context, and how technology impinges. On this view the introduction of a new technology, such as advanced IT, will affect and be affected by customary ways of doing and thinking about things. In this study we favour the *praxis* model as an alternative to the rationalistic-deterministic models that are so prevalent in thinking about technology.

The rational decision making model

The dominant characteristic of the rational decision making model is its grounding in detached analysis. On the rationalistic view, the management of a practice should undertake extensive *analysis* of the practice's operations, and of the market for their services, prior to the introduction of IT. Management are urged to quantify factors such as the volume of work undertaken, task completion times, and staff development costs. After the introduction of IT, emphasis is placed on "proving" or quantifying productivity gains (or losses) (Dill and Pitman, 1985; Architectural Record, 1990).

There are many limitations to the rationalistic model. First, it is very difficult to assess productivity, beyond what financial balance sheets indicate. If productivity is related to inputs and outputs, then inputs include investment in staff time and capital, and outputs include jobs completed, profits, kudos, greater potential for future work, etc. Both are difficult to measure. Second, the very premise of the rationalistic model-that new technologies are adopted because they increase productivity-has been thrown into question (Forester, 1989). Third, there has been a significant backlash against the application of "rationalistic" principles in business. Peters and Waterman (1982) observe that a narrow focus on "objective" analysis has led to the marginalisation of strategies that make the top American and Japanese businesses successful: customer service, encouragement of employees, making products that last and work, and relying on intuitive evaluations of the market. The evidence of our study is that practitioners do not really follow the rational decision making model, though it features prominently in the way some practitioners talk about their firms and IT.

Practitioners are adept at explaining their decisions in rationalistic terms, and then just as readily betraying that model by talking about the legitimacy of other modes of decision making, such as adopting CAD because everyone else is doing it, or doing what feels right. Tensions emerge between an underlying belief in the rationalistic principle that productivity gains and losses should be quantifiable, and the practical recognition that manual and automatic techniques aren't readily comparable:

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It needs a bit of work to set up but once you're set up it goes much better.
There are some things that you don't do manually because you haven't got the
resources-it's not readily comparable.
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There is also an emerging sense that information technology is *essential* technology, that extensive justification is unnecessary. A practitioner from a government department described this change as follows.

> There was a policy once that everything you bought that had to do with computing had to go through a Board of Review (5 or 6 committees) [implying the need for justifications]. Now they regard them as typewriters-they're not interested.

It was clearly evident from our survey that practitioners are making technology related decisions on the basis of situated, context sensitive judgements rather than on the basis of detached analysis. We draw attention to the rational decision making model here as it is a prevalent view that appears to impede an understanding of what is really going on as IT is incorporated into design practice.

The model of technological determinism

Technological determinism may be defined as the belief that our future is being shaped by technology. Forester contrasts "determinism" with "free will," the belief that "we are to some extent free to choose and shape our future" (Forester, 1989, p.2). On the determinist view, the actions of individuals and groups are less influential in change than the enormous impact of technology.

Comments by practitioners provide evidence for the prevalence of the deterministic model. Some practitioners speak of a "natural progression" in improvements to machine speed, photo realism, user friendly interfaces, integrated building models and data exchange standards. Some think that obstacles currently impeding the technology will be overcome with technological solutions that will occur almost "automatically."

[CAD management] is a reducing requirement. In the next ten to fifteen years the increase in the use of AI [artificial intelligence] will mean that the management of systems in terms of making sure that you've got the right layer, with the right things on it, in the right place, in the right file, on the right job, at the right time-you are going to need that [AI]. A lot of the tedious stuff will be dealt with automatically by increasingly sophisticated software.

Within this model it is assumed that the groundwork for CAD has been laid. The future consists of more of the same with the impediments overcome. The incorporation of CAD into practice is progressive and evolutionary. CAD use runs according to a fixed course. As one practitioner put it, "there's no need to predict the future because it's already been predicted for us." In other words the future is determined by the technology.

Determinism is at play in the explanations that some practitioners give for their move into CAD, and into technology in general.

…we thought it [CAD] was inevitable. We wanted CAD as soon as we could get it. We wanted to be early. No matter what the price we figured you had to start.

You will get to a stage where unless you can operate these machines you won't get the jobs.

… you don't have a choice. If you want to survive you have to follow the technology. A lot of people feel that they're being pushed into it-which they are.

Within this model, the inevitable "progress" brought about by technology may be viewed in either a positive or a negative light. For some it is the portent of opportunity. Reading future trends and acting accordingly opens up the possibility of consolidating market share and establishing new markets. For others it poses a threat. They think that there *will* be change and that they will have to comply with that change. There is a sense in which they are being forced to comply with the dictates of the technology, dictates that are beyond their control.

In its most mundane form technological determinism takes it for granted that there is an incremental continuous path that is "progress." Symptomatic of this "continuous path" outlook is the emphasis placed on the "fact" that microchips double in speed and memory capacity every three years. They have done so since the late 1960s and, according to the incremental technological determinist, will continue to do so into the future. A variant on technological determinism is to hold that technological change is *discontinuous.* According to this view, technologies introduce radical *discontinuities* into our work practices. Thus practitioners speak of changes from a labour intensive office to a capital intensive office, from a craft based industry to a production line.

The issue ten years ago was whether you wanted to do it or not. The issue today is *how*. The issue in ten years time will be those who have and those that haven't. It's just the evolution over twenty years of going from a craft based office to a production line machine based office.

Implicit in such characterisations of radical change are calls to *appropriate* or adapt to the change; calls to rethink the nature of architectural practice and the implications of information technology.

The praxis model

The *praxis* model is characterised by its emphasis on everyday practices. According to this model we are socially situated. We are deeply embedded in culturally defined patterns of activity. These patterns of activity shape the way in which we take up new technologies. Furthermore, new patterns of activity, new practices, may emerge as new technologies are incorporated into our everyday ways of doing things.

In the praxis model we recognise that technologies and practices interact in complex ways. According to the praxis orientation the introduction of information technology into a firm constitutes a perturbation in the praxis of the firm. The introduction of information technology disrupts customary ways of practicing architecture. In the process the technology is also undergoing transformation.

The nature of praxis is evident as we consider the relationships between members of a firm, particularly those relationships that cross over the organisational structures and the formal roles of the participants: the tacit understandings of the boundaries to each others knowledge; knowing who to turn to for help; knowing who is reliable and trustworthy; and the teams of alliances that are set up.

Technologies are similarly connected to each other. They form parts of complex technological systems that include: physical dependencies, such as the dependence of computer systems on the electricity grid and the telephone system; metaphorical dependencies (CAD systems are related to manual drawing tools, multimedia is related to film and video, aspects of electronic mail are related to telex and CB radio, and so on); institutional dependencies (through industries, systems of distribution, regulations, training and education systems); and local dependencies (the computer requires the printer, the modem connects the computer to the telephone line, and so on).

These technological constellations are enmeshed with the complex constellation that is *praxis*: the role of the designer is meshed to the technology of the drawing board or CAD system, and their related technologies; the role of the manager is caught up with spreadsheets, the cellular telephone and the company car; secretaries and administrative assistants are involved with typewriters, wordprocessors and telephones. This interconnection of praxis with constellations of technology is particularly evident if there is a change in any of the components. A simple example is the introduction of word processing, which is gradually changing, and reducing in some cases, the role of the administrative assistant. But the effects are not just in one direction. Wordprocessing has been designed and developed through understandings of typing practice, and the technology is responding to changes in that practice as word processing incorporates more features of interest to management, such as the incorporation of dynamic charts and tables.

The *praxis* model recognises that new technologies *reveal* aspects of our practices: CAD reveals architectural practices as custodians of databases on buildings; computerised desktop publishing reveals architectural practice as a kind of publishing business; and multimedia reveals the firm as a dealer in advertising, presentation and even fantasy. So technologies do not merely meet needs, but are implicated in the defining and redefining of practice.

The praxis model critique of rationalism

From the point of view of the praxis model the *rationalistic model* presents too narrow a view of change. Whereas the rationalistic model emphasises change made on the basis of explicit decision making, the praxis model allows for the notion of change as a cultural phenomenon without a single rationale.

Very few professional designers have changed to date… This will change as a new generation of students come through that see the computer in the same way that the current generation regards a drafting board.

We spend 15 years learning to draw with a pencil-it's a language. You're putting things down for another person to understand your concept of a future reality. CAD just does that in a different way.

The praxis orientation is evident in the way that practitioners talk about taking up CAD on an "experimental" basis in the absence of any clearly articulated rationale.

I don't think that they [the firm] actively made allowances for anything that may or may not have happened. I think they just decided to get into information systems and see how it went and they had a management structure that coped …

Before I joined this company we had been on a bureau to a North Sydney company. We went into CAD in a non-committal way so we knew what we were doing when we finally purchased a CAD system five years ago. A lot of companies bought a CAD system without knowing what they were doing.

The motivation for a practice taking up CAD may have more to do with the *expectations* of clients and staff (implicit in the client and office cultures) than with "objective" estimates of productivity gain.

… the reason that any organisation gets into CAD is that there are staff that want it and they exert pressure on management. It's hardly ever taken objectively…

… 99% of architects go into CAD for the wrong reasons, the client expects it: "without CAD you're not up to date."

Clearly there is a tension here. The praxis model suggests that rather than dismissing "client expectations" as irrelevant, or irrational, we should recognise the importance of the expectations embodied in client cultures.

The praxis model critique of determinism

The praxis model makes sense of the experience of some practitioners that they are being forced into IT, and that "the future has already been predicted" for them. It does not, however, buy into the deterministic position. According to the praxis-based model action always takes place within a context of communally defined *praxis*. Responses to information technology take place within this context. Individual practitioners feel the weight of the evolving norms and conventions as they adopt new technologies.

All the firms are going into IT. So to keep up with other firms you have to start using it.

A lot of them [design practitioners] are taking the approach that CAD is coming so we might as well jump on the bandwagon now.

The praxis orientation distinguishes itself from determinism in that it leaves room for the fact that conventions change. In fact it recognises that change is the norm. Not only does adopting computers promote change, but it also *reveals* change. The adoption of a technology brings change into sharp relief.

People get the idea that once you get computers there's a set way of doing things-people are always changing the way that they do things and the way that you set things up on the computer has to be such that you can adapt to that change. It requires a great deal of management and computing skills to get those things working properly.

The shape of the future is not inevitable; nor is the way in which we will make use of technology.

According to the praxis-based model technology does not *determine* change. Technology is rather one of many interconnected factors in the constellation of actions that is praxis.

IT Strategies in Practice

The deterministic and rationalistic models foster simplistic readings of the "impact of technology." Commentators on technology put forward *a view* of the office of the future. It is implied or assumed that the majority of practices will move in this direction.

The praxis model, on the other hand, acknowledges the plurality of possible responses to technology. In the light of our survey of architectural practitioners we have found it useful to classify these responses as follows:

operating without advanced IT;

substituting IT for traditional activities;

delivering traditional services in new ways with IT;

extending the firms services through IT.

The response of an architectural practice to technology is the result of a complex interplay between available technologies and entrenched practices. None of these approaches is necessarily superior to the others. Different strategies will be appropriate for different practices at different times. Furthermore, any individual practice may adopt a variety of approaches. We also assume that a firm may be unaware that it is following a strategy at all.

Operating without IT

A cursory glance at the literature pertaining to the use of IT in architectural practices is likely to leave one with the impression that all practices are using IT, or will be doing so in the near future. While the data available indicates that a majority of architectural practices are using IT there are a significant number of practices that do not make use of the technology. Furthermore at the time of this study only a minority of practices in Australia, the USA and the UK use CAD.

Various studies have shown that CAD has become the norm in large practices but not in small practices. Why have small practices automated their business functions but not embraced CAD? Why are there a significant number of practices that do not use the technology at all? Various explanations are offered.

(i) Smaller practices consist of a fairly high proportion of professionals who are design oriented. It has not been the designers who have been using CAD.

Very few professional designers have changed [to CAD] to date … It's more the documenters and the managers that are taking it on at the moment.

There are a number of reasons why professional designers haven't taken on CAD: they don't understand it or understand what it can do for them, they feel that it will impose on their designs or on the ways in which they have become comfortable with designing, they simply don't like using CAD, they don't like the kind of output you get from CAD, they don't want to be classified as a computer operator, they don't want to be "at the mercy of technocrats," they feel that it will take too much time to learn, or that it will be too expensive. These attitudes are changing as computer systems become more oriented to designers, as graphic design and media people become more involved in the development and use of computers, and as IT becomes incorporated into everyday practices.

(ii) Smaller practices typically have different projects, different clients and offer different partial services than larger practices (Cuff, 1991, p.45; Dean and Olley, 1988). Whereas the clients of the larger practices (corporations and government organisations) expects the practices to have CAD, there is currently no such expectation on the part of the home owner or the smaller commercial client, both traditional small practice clients. Indeed automation may be perceived as detracting from the "personal" approach required by the small practice client (Architectural Record, 1984).

I think most small-office clients are primarily entrepreneurs who own or control their own business … It's one ego

massaging another ego, and if we brought in a computer plot program, most of our clients would be outraged because they would feel we weren't giving our personal artistic or interpretative attention to their job. Our clients are terribly interested in their [architectural] programs, and they want to feel that the principals or the people that they are dealing with are working with them on a very personal basis.

The designer in the small practice is likely to be dealing with small scale, one-off projects, with minimal repetition of elements-factors which militate against the necessity of CAD. The small practice is more likely to offer partial services in the area of design or in a specific area of design expertise rather than in documentation or management (Gutman, 1988, p.22).

Interestingly, the primary projected advantage of a small firm embracing CAD is that it will allow the firm to undertake larger projects.

… the era of the backyard operator has arrived. … I know of several circumstances where two competent architects with a CAD system are doing large projects extremely competently and I would imagine extremely cheaply. So it empowers people with the skills to be closer to whatever it is that they want to be closer to rather than hanging around an office.

CAD is perceived as being a means of allowing the small practitioner to move into the kinds of projects that are highly coveted by the profession, without sacrificing the autonomy possible within the small practice. CAD is also regarded as a medium with the potential to provide a seamless interface between practices and consultants. From the point of view of the smaller practice this provides a new opportunity, allowing them to plug into larger projects.

(iii) A final factor at play in the reluctance of the small practitioner to embrace CAD is the extent of commitment required. Large practices can afford to have the technology in place just for those projects that are "good for CAD." CAD does not have to be integral to the overall operation of the firm. For small practices the decision to move into CAD is a commitment of the entire direction of the firm.

If we look at the applications that are taken up most extensively in architectural practices-word processing and spreadsheets-we find that they are very different types of applications to CAD. They are low cost, relatively easy to learn, offer instant gratification in the form of quality of output and flexibility of operation, and they don't impinge on core design skills. In fact applications such as these are considered to be instrumental in freeing up the designer from the more mundane aspects of practice so that she can concentrate on core activities. Furthermore these applications are widely used throughout the business world. They are already part of the small business culture.

Why has the widespread use of applications such as word processing and spreadsheets not seeded an interest in CAD. (According to Crawford and Huchinson's survey 45% of small practices (1-4 people), and 10% of medium practices (5-14 people), aren't using computers.) One factor at play is that practitioners simply do not know what is possible with computers. Olley (1991) found in a survey of 283 offices registered with the RAIA (Royal Australian Institute of Architects) Practice Division that there were many requests for the Practice Division to evaluate software and provide education and training, these requests were from offices that were, in the main, already using computers.

Another factor is the conception of computers and anything to do with computers as the antithesis of designerly ways of doing things. Computers do not fit in to the firm's understanding of its role, and the roles of its participants.

… for a lot of lay people the idea of a computer is completely tied up with the idea of cold, hard-headed rationalism, and this actually prevents a lot of people from accepting or using the technology because they would consider accepting computers to be the same as accepting a cold, hard-headed, rationalistic approach to life. If we could break down the concurrence in people's mind of computing and rationalism, a lot of interesting things could happen with computers in practice.

Finally, there may currently be no need for computers in the smaller practices. The "minor job" represents a significant sector of the architectural market. Furthermore, small practices may choose to specialise as "design architects" (Gutman, 1988, p.102) or offer other specialised service. Traditional office procedures may be entirely adequate in these markets.

Substituting IT based tasks for traditional tasks on a one-to-one basis

The prevalent strategy in practices that have adopted IT has been to substitute IT based tasks for traditional tasks on a one-to-one basis. The typist now uses a word processing package as a substitute for a typewriter; accountants use accounting packages as substitutes for file cards, Kalamazoo, etc; the draftsperson uses CAD in place of drafting board and pens; and the architect explores plot ratios using a spreadsheet rather than sheets of paper and a pocket calculator.

This substitution strategy affords a certain security to practitioners, particularly when it is phased in incrementally. Disruption of normal work patterns is minimised. Users are given an opportunity to become comfortable with the technology. Management are provided with an opportunity to experiment-to find out what works and what doesn't, and how people like to use the technology. Many practitioners are wary of becoming overly dependent on the technology-they don't want to have to employ dedicated technical personnel (systems managers) nor do they wish to be "held to ransom" by CAD operators. They don't want IT to impinge on the traditional values of the practice. Introducing the technology gradually would seem to be an appropriate strategy for keeping those values intact.

On the other hand there can be drawbacks. There are many who would argue, theorists and practitioners alike, that this kind of piecemeal approach will not allow the technology to be used productively (Harris et al., 1989, p.370). It is, in fact, a common perception amongst architectural practitioners currently using CAD that they are *not* using it productively. Furthermore the substitution approach can result in serious rifts between IT personnel and management. In the worst case scenario a practice may purchase a CAD system because their clients demand it and rely on junior staff to get it running, providing neither training nor management support. There is a lack of recognition that the new technology requires the development of new practices.

Initially, the technology may be introduced as a substitute for conventional tools and methods. The most successful marketing of computer systems appears to exploit this. The available technology may in fact lead to the construction of specific sub tasks within the firm. One of the practitioners interviewed identified a number of key roles for himself-secretary, accountant, graphic designer-roles aligned with the software tools incorporated in his practice.

> Moving from senior management to a small business practitioner, I'm using all the tools to avoid putting on junior staff … You become a secretary, an accountant, a graphic designer because you're in the business of selling information and you have to present that information professionally. The level of information presentation is very high.

As the firm begins to accept the technology and as it becomes integrated into the firm's praxis, the more innovative aspects of the technology may emerge and be exploited.

Innovative delivery of traditional services

The culture of architecture is one in which innovation is highly valued (Cuff, p.52; Blau, 1987; Saint, 1983). Innovation is also an important aspect of management culture (Peters and Waterman, 1982). It is now a familiar line of argument that organisations will only reap the benefits of technology if they restructure their operations. Radical changes in the praxis of the firm are implied. Those practices that have developed innovative ways of delivering traditional architectural services are regarded as "creative leaders."

They [the practices that are experimenting with new ways of working and designing] are probably the same practices who would have been creative had they not had computers.

It is important for those architectural practices with corporate and government clients to be perceived as being progressive. Merely having computers has, in the past, been an important factor in such perceptions. As computing use becomes mainstream, "client perception" is likely to provide the impetus for new services. These services will exploit both traditional architectural skills and the possibilities created by computing technology. Our study of practitioners confirms several "standard" innovations that have been incorporated by practitioners.

(i) The development of databases of CAD details for use in multiple projects. Most practices that use CAD for detailed documentation establish libraries of details that can be pasted into any number of projects.

(ii) The development of *specification* databases. The query and report writing facilities of database programs make them suitable for the production of specifications for complex projects. These specifications may be used throughout the administration of the project, and in the post occupancy administration of the building. There have also been attempts to develop specifications for use in multiple projects. Examples of such standardisation include corporate space standards and "generic" specifications for complex building types such as hospitals.

(iii) The use of *CAD databases* in the ongoing administration of projects. CAD can be used for more than merely drawing up proposals. Queries can be made about dimensions and offsets and areas. This facility can be valuable during the course of administering projects.

(iv) The organisation of drawing production so that each documentation drawing is linked to related drawings. This is considered important in maintaining consistency between drawings when variations are being documented.

(v) The organisation of the tasks in such a way that CAD operators sit alongside the designers and model proposals as they are being developed. Designers thus become familiar with the technology and what it can do for them without distracting them from design.

(vi) Restructuring the production of correspondence (letters and memos) so that secretaries (or practitioners) are responsible for the text but a graphic artist or designer is responsible for the layout.

(vii) Using the resources of the accounting personnel in a more dynamic way, including requesting weekly rather than quarterly reports, and having management and practitioners work with spreadsheets.

(viii) The use of electronic communication facilities for remote collaboration on projects.

Practice innovations such as those outlined above may occur informally in smaller practices, but require a commitment from management and often the commitment of substantial resources in larger practices.

Amidst the futuristic outlook of the "technologists" and the promotion of innovation within architectural circles there is an emerging sense that it is not necessarily a good idea to be "leading edge." Investing in the development of computing tools can be costly. Projects and work practices change. Databases of details or specifications may only have a limited lifespan. Finally, the model of IT and practice held by the firm may be holding it back. One of the difficulties arising out of the *rationalist* model is that there is a tendency to look to technology for a "solution" to everything. The rationalist model conceives of the building industry as unnecessarily fragmented, documentation as unnecessarily ambiguous, and design as unnecessarily inefficient. Integrated building models, complete project descriptions and comprehensive suites of analysis programs are obvious "solutions" to these "problems." The "problem" from a praxis-based point of view is that the

rationalist is overlooking the importance of everyday communication and work practices. The "problems" perceived by the rationalist are, by and large, not "problems" to be "solved" but realities of the practice of architecture and of the construction process and its participants-the total field of praxis.

Developing extended services

Information technology opens up significant opportunities for architects to extend the scope of the services that they offer. Some technology based areas into which architectural practices have diversified include desktop publishing, designing computerised slide show presentations, facilities management and computer consulting. The motivation for *diversification* include the provision of a comprehensive service to clients; exploiting existing investment in equipment and training; and countering the vagaries of a cyclical market for services. This type of approach seems to be viable in both large practices where there is management commitment and in small practices-indicating the scope that IT can offer the small practitioner.

Of course, diversification can also be perceived as detracting from core design skills. Cuff (1991, p.39) observes that architects have traditionally "sloughed off" constitutive skill areas, allowing them to become professions in their own right. Thus we have the emergence of the profession of quantity surveying to deal with building economics, structural engineering to deal with the mechanics of building design, and project management to deal with the coordination of the construction process. There is some evidence that the same is happening in relation to computing with the emergence of the *CAD consultant*.

IT and the role of the architect

The practice of architecture involves a broad range of competencies. What we do as practitioners is shaped by the roles that we "play out." It was evident from our survey that the existence of IT is extending the roles available to the architect. In particular we have the emergence of the notion of the architect *as information generator*. Another interesting phenomenon evident from our survey is that the roles with which practices and practitioners identify influence their response to IT. Allegiances to the roles of architect *as form-maker*, architect *as generalist*, and architect as *business professional* have an important bearing on those aspects of IT considered to be significant to the profession.

The architect as information generator and coordinator

Increasingly, CAD is being understood not just as an alternative to manual drafting but as a database. An opportunity exists for architects to recast themselves as generators and coordinators of building information. This is precisely what has been happening in the area of facilities management. Responses to our survey indicate the potential to develop this role throughout the design and administration of a project. Practitioners suggested that architects should promote the fact that CAD allows up-front checking for inconsistencies in documentation, immediate responses to queries, and fast propagation of design modifications throughout the documentation of a proposal.

To make a CAD drawing more complete a lot of the design work that may have been done on a piece of paper on the site has to be done at the documentation phase-for a correctly done project this may make the documentation stage longer than if done manually but it greatly reduces the construction phase-because everything is thought out it's very accurate because it's on CAD and there are less mistakes and less question marks-I think clients should be made aware of that fact more than they are.

If the state manager says "what's the gross area?" you can tell him in half an hour if it's on CAD. When it's done manually it will take you three days plus or minus 20%.

… one of the great attributes of our system is that we can write macros very easily. …[In one project] there were 260 client induced variations all of which were tracked perfectly in our written database and on our drawings. The job captain, who was a director of the company, knew at all times that those amendments were up to date. The speed with which we could

get those amendments back to site was very fast. That endeared us to the process of construction which meant that everything went smoother. We now believe that we could not have done that project without CAD.

Concept designs tend to be on butter paper but they are transferred very quickly to CAD, some manipulation is done, then you spit it out on the laser [printer] so that you're actually dealing with real dimensions, and then work on butter paper again...

This change in understanding from CAD as an automated drafting tool to CAD as a powerful graphic and non-graphic database provides the incentive for designers, as well as just draftspersons, to start using the technology. Architectural practices become the source of information about buildings. The building database becomes a source of detailed information including information about site coverage, floor areas, dimensions, inconsistencies in the documentation, and 3D projections.

Foremost amongst the concern of practitioners is the need for improved data exchange standards. This reflects a recognition that there are significant gains to be made from pooling the output of the various professions involved, to create graphic databases describing the project. The fact that many facilities management consultants advise organisations that they should maintain CAD databases in-house reflects the increasing recognition that such databases are a valuable resource, both in the construction and in the ongoing administration of a building project. Practitioners consider the advantages of CAD databases over traditional documentation to be easy modification, and increased accuracy and flexibility in the way the data may be viewed and interrogated.

Photorealism: architect as form maker versus architect as generalist

Photorealism involves the production of computer images of CAD models that include realistic surface detail and lighting conditions usually generated through ray tracing and radiosity techniques. Architectural practitioners are divided in their assessment of the importance of photorealism. On the one hand a majority of practitioners felt that photo realism would be of great importance. On the other, a number of practitioners with extensive IT experience expressed reservations about the importance of high quality renderings:

We don't do full colour 3D modelling even though our system has ray tracing capabilities because we don't believe that those fully rendered 3D images necessarily communicate anything that the project is about more effectively.

We produce audiovisuals which are computer encoded slide shows that use six slide projections on the one screen to promote projects-the monorail, the festival marketplace-all were spawned in that way. So we've been a mixed media communications company as much as an architectural firm. We go from the dream making end of it all the way-which is where I think architects are using computers in really old fashioned ways. They think that clients are only interested in perspective views of what things look like and they cannot express what projects are about. That has meant that we've had a pretty wide exposure to the kinds of tools that are available, we've been producing our own media as well as our own technical documentation on large projects.

Attitudes towards high quality rendering tools reflect deeper divisions throughout the profession as to the role of the architect. On the one hand there are those who consider the task of the architect as first and foremost that of a form maker. Amongst this group the emphasis is on the artefact. Photorealism figures prominently as a potential technique for presenting the form of that artefact. On the other hand there are significant numbers within the profession who have long argued that the role of the architect should be much more comprehensive. For these practitioners issues such as communicating with clients, delivering expert advice, and being involved in the ongoing supervision of projects are high priorities. Photorealism is peripheral to the suite of IT tools relevant to these practitioners.

Interestingly, at the time of writing, there are few architectural practices that have taken up photorealism. There are a number of reasons why this may be the case: the quality of output, the specialised nature of the software and expertise required, and the amount of work involved. Creating high quality perspective renderings is a time consuming and highly specialised task, even on computer.

There is however another important factor at play. Rendered perspective images are not necessarily pivotal to either the design or communication of an architectural project. Designers are used to working with abstractions. Simple wire frame models which can be generated and manipulated quickly are often of greater benefit to the designer**.** Clients on the other hand are concerned with issues that extend beyond the appearance of the building. The client is interested in the real value of the project being proposed: image is important but so are construction, maintenance and ongoing operational costs. Designers concentrate on communicating how the proposal will be used, how it will be appreciated, and the commercial advantage that it will secure rather than simply what it will look like. Rendered perspective drawings are not necessarily the most appropriate medium for communicating this kind of information.

Clients are also interested in ensuring that they are receiving a high quality service. CAD is perceived by practitioners as being an important marketing tool but it is a misconception that this has to do with the quality of the images that can be produced. There are two principal ways in which CAD brings a marketing advantage to a firm.

(i) The mere fact that practices have CAD is a useful public relations exercise. The practices appear up to date.

(ii) It is necessary to have the drawings on CAD to collaborate with other client consultants, such as interior designers.

Finally, the communication involved in the development of a successful project is two way. One practitioner commented that even in the case of plans, highly finished computer generated output can inhibit the client from making valuable contributions to the process.

> It's interesting what it [presentation techniques that simulate manual drawing] does for clients' perceptions of drawings-I laughed at it to begin with, I thought it was a real con … but there's a point to it-clients are much more inclined to have some input into drawings that look rough.

The production of highly sophisticated rendered images is likely to deter both designer and client from developing a design further. Interestingly, many practitioners feel that walk through animations will be important for client presentations. Animated sequences have the potential to communicate much information about how the building will be perceived (visually and kinesthetically) and used, without relying simply on the abstract sketches commonly produced by designers.

The architect as business professional (with IT support)

Jones (1982, p.173) provides an illuminating insight into the central role of information services in Australian society.

> Australia is an information society in which more people are employed in collecting, storing, retrieving, amending, and disseminating data than are producing food, fibres and minerals, and manufacturing products.

An increasingly information intensive society inevitably leads to new ways of doing business and new expectations from clients. What we will see, and are seeing, is a shift away from the situation where the client relies on the understanding and recommendations of senior members of the profession. According to Jones it will become increasingly important to support these tacit judgements with the kind of research and modelling that is being adopted across the board in business.

The widespread availability of information technology entails increased expectations for high quality presentation at all levels. This applies at the level of the firms "paper work." The principle of re-using

elements from a central database can be applied throughout a practice's operation. Cut and paste operations can be used to incorporate both text and graphics into a firm's "correspondence" thus facilitating the delivery of a consistent and distinctive image.

We took the attitude that every letter that we sent out of here was a desktop publication. Therefore, rather than expecting typists to have graphic skills, we liberated it completely from that and just asked them to put it in, then our graphic designer would manipulate it. Everything that we were writing became very important because ultimately we can cut and paste and re-publish in different formats. Your potency in all your submissions increases because of that-issues of policy and philosophy that can be stated universally and thought through carefully can be patched through all your projects as a quality control device. So you're delivering your own corporate promise from that database.

As management and accounting software becomes the norm in the business community architectural practices will be expected to keep pace. Olley (1991) found that 47% of 283 Australian architectural practices surveyed were using accounting packages and 28% of those practices were using project management software. Crawford and Hutchinson (1990, p.11) found that 34.9% of 152 New South Wales based practices surveyed used job costing software. Maintaining good internal management records will become increasingly important in an increasingly competitive and specialised environment.

IT and the micro practices of the architectural office

The day to day practices in which architectural personnel engage are important in determining the culture of a practice. Our survey revealed an interesting interplay between IT and those micro practices. In particular it reflected a diverse range of opinions on the following issues:

does IT lead to deskilling or reskilling?

does IT enhance or detract from the exercise of core design skills

does IT facilitate autonomy, is it an essentially isolating phenomenon, or does it reinforces the interdependence of a matrix of practices and players

The diversity of opinion with regard to these issues indicates the complexity of the way in which IT impinges on the practice of architecture. As might be predicted from the praxis model, it is not IT in itself that determines changes in the micro practices of the office, but the interplay of IT with entrenched attitudes and practices.

Deskilling or reskilling

The most significant item of software in architectural offices in terms of skills required is CAD. The principal determinant of whether involvement with CAD is perceived to lead to deskilling or reskilling is the degree of autonomy associated with CAD usage. Two strategies appear to have been effective in preserving the autonomy of the CAD user. (i) The designers use CAD in the course of working on their own projects. They maintain a sense that they have control over the design as well as documentation. CAD is thought of as a rich new medium for producing designs. (ii) An alternative strategy is to identify CAD operators as a distinct category of personnel and to restructure the way that work is carried out so that an appropriate interaction between designers and CAD operators is achieved.

What we found is that our designers were frightened of CAD. So we put them [designers and CAD operators] side by side and as concepts were generated, even though they might be crude, the CAD operators would model them. So pretty quickly these 3D models started to follow up the designer and the thing that he was thinking about yesterday was on his desk at lunchtime the next day in three dimensions. So the designer became interested enough in CAD to take the model over and to manipulate it slowly himself. That was a better investment than demanding that the designer get the CAD skills of a racing car driver [an experienced CAD operator]… CAD operators and designers operate perfectly well together if you leave them to do their job and if management understands the different things that they're doing on that job.

The perception of involvement in CAD as leading to tedious dead-end work appears to arise primarily when CAD operation falls to junior personnel by default. Where there is a perception that design is being monopolised by senior personnel, with junior personnel merely drawing up their ideas, then the use of CAD is thought of as tedious by both parties.

Unfortunately there has been considerable reluctance to recognise CAD operation as a distinct category of skilled activity. Shugg(1993), for example, argues that it is paradoxical that the most expensive item of equipment in the architectural office (CAD) is operated by the most inexperienced staff (draftspeople, junior personnel). From this perspective it seems imperative that designers, rather than less qualified or differently qualified staff, become the primary users of the technology.

There are, however, a number of problems with Shugg's position. First, CAD systems are difficult to operate. Drafting constitutes only one aspect of the day to day activities of the architect. The complexity of CAD software makes it difficult to marry skill in CAD with the more general spread of skills required to practice as an architect. Second, many practices have for years been able to make good use of a division of labour between designers and draftspeople. Since the principal productivity gains associated with CAD are in the areas of modification, re-use and database interrogation rather than in the initial creation of drawings then it makes sense to continue to allocate that task to draftspeople. Finally, it is true of all industries that mass data entry falls to less qualified personnel, no matter how expensive the equipment they are operating.

Enhancing or detracting from "design"

Design is a highly coveted activity amongst architects (Cuff, 1991). It is significant then to ask whether practitioners perceive that IT is enhancing or detracting from the exercise of design skills (and thus the quality of designs produced). Many predictions have been made as to how computers would enhance design. These include:

computers would generate designs automatically;

computerised procedures would force designers to be more logical and would thus produce better designs;

IT would free designers from more mundane routine aspects thus allowing them to concentrate on design;

IT tools would allow designers to produce multiple options thus enhancing their creativity.

We will consider each of these predictions in turn.

(i) Computers will generate designs automatically. The practitioners in our survey readily acknowledged the once prevalent notion of "automated design":

Interviewer: What do you recall were the major predictions regarding computers in design ten years ago?

Practitioner 1: Software that would design the whole building after entering a few options.

Practitioner 2: All that you would have to do is punch in all the parameters and it would go away and give you a complete office tower.

The practitioners also acknowledged that the promise of "automated design" had not been realised, and further held the firm belief that the automated generation of designs was not possible. Various reasons were offered as to why it was not possible to automate design.

An architect makes a snap decision that would require an expert system to sort through hundreds of variables, and the

database has to be up to date. An architect might not make the correct decision but he makes it instantaneously taking all sorts of abstract concepts into account.

…the moment you try to create standards is the moment that people try to change them but there would be a lot to gain…

Despite the practical recognition that it was not possible to automate design there was an uneasiness amongst some practitioners about why this should be the case.

The once prevalent belief in "automated design" is a legacy of the early design methods movement, or more generally of rationalism. According to rationalism, design decision making is, or should be, governed by systems of rules. We should be able to make those rules explicit. We should be able to analyse a design situation objectively, identifying the variables and objectives that define the situation. We should be able to apply rules to develop a solution that is "the right solution" for a given situation.

At the heart of the problem with rationalism are assumptions about the nature of decision making. It appears that decision making is not a matter of following a set of context free rules. If it were, how would we know when and how to apply those rules? The kind of judgement required in decision making is necessarily prior to the formulation and application of rules. It involves taking into account an understanding of what is important in a situation, what is to be expected from others, what is an appropriate way of acting.

What is the basis of such understanding? To relinquish rationalism is not to assert that decision making is arbitrary. According to the *praxis* model decision making is grounded in patterns of thought and action that integrate a culture and define an individual's relation to it. Individuals are constantly being inducted into socially defined patterns of thought and action. These cultural norms are typically taken up unawares. They govern the way we dress, how closely we stand to one another, the tone of voice we use in a given situation, how we act out the role of architect, designer or client. They also govern the possible stance that an individual may take up in relation to science, politics and religion. They govern our work practices and are constitutive of the roles that we take up in society. These patterns are not static-they are always changing.

Decision making occurs in the context of these patterns of thought and action that have been ingrained in an individual by the culture or cultures in which that individual participates. Only in the most elaborately constructed situations could it be suggested that this decision making has the character of *rule* following.

(ii) Computerised procedures force designers to be more logical and thus produce better designs. One aspect of the commonly accepted view that rational decision making is a matter of following context independent rules is to brand designers as *illogical.* Computers are thereby seen as a competitor to designers-the superior capacity of the computer to consistently follow rules shows up the inadequacies of the designer.

It imposes stress because you are going from a craft based industry to a building production line process-you have to do things in a logical order, a lot of architects and people managing design don't think logically and they get caught out.

Adopting the rationalist stance implies an agenda for reforming practice: analysis programs should be run from the earliest stage of design; design expertise should be made explicit; designers must change their ways to conform to the "logical" mode of operation of the computer. The payoff for conforming to "logical" modes of practice would, according to the rationalist position, be better designs.

An architect makes a snap decision that would require an expert system to sort through hundreds of variables… An architect *might not make the correct decision* but he makes it instantaneously taking all sorts of abstract concepts into account.

There are a considerable number of processes that a designer goes through that are logical processes-they will never produce great designs, they will never produce the Opera House, but they will produce a lot better than the average design solution that you will get from the average architect, mainly because it was produced in a logical way.

Once again this position can be criticised from the point of view that rational decision making is not a matter of following rules. Rational decision making does not have the character of a computer algorithm. While there is no doubt that the introduction of IT into architectural offices requires the development of new organisational skills it is inappropriate to characterise these skills as more or less "logical" than those already in place.

Another effect of the existence of the rationalist stance has been to legitimate the category of the romantic. Foremost among the concerns of designers in making the move to CAD is the "mode of input"-they don't want to lose the primacy of working with pencil on paper. Many designers speak of a left-brain/right-brain conflict, particularly when first learning to use the technology.

While the difficulties that designers experience in adapting to the technology are important, couching these difficulties in left brain-right brain terminology implies a confrontation of two different modes of thought. Designers can, and do, master the technology. The difference would be better thought of as a difference in media. Designers can exploit the best aspects of both media, there is no requirement that they completely abandon one in preference to another. A practitioner in a small practice adopted just such a hybrid approach.

Concept designs tend to be on butter paper but they are transferred very quickly to CAD, some manipulation is done, then you spit it out again on the laser so that you're actually dealing in real dimensions, and then you work on butter paper again.

(iii) IT will free designers from more mundane routine aspects of practice thus allowing them to concentrate on design. This belief appears to be manifest in two different ways. On the one hand there are those practitioners who believe that some of the "thought processes" that a designer uses can be captured as computer algorithms. By capturing those "thought processes" those "logical" parts of the design process could be undertaken by the computer leaving the designer free to concentrate on the more creative parts of design. This approach is subject to the same problems as those of "automating design."

Alternatively there are those who use tools such as spreadsheets and word processing packages as design tools.

I use a Mac all the time now. When I feel like doing things, I flick through things I haven't thought about for a month and think more about it-your ideas don't just drift away.

(iv) IT tools will allow designers to produce multiple options thus enhancing their creativity. One of the earliest predictions made in relation to CAD was that it would allow the designer to explore multiple options. Considerable effort has been expended in developing programs that generate design options. It was evident from our survey that practitioners have not taken up these programs. The principal benefit of CAD from the practitioners' point of view is that it allows them to modify proposals. This use of CAD concurs with findings of Darke (1979), Foz (1973) and Hillier et al (1972) as to the nature of the way designers develop proposals. Designers "generate" an initial scheme from the earliest stages of design and modify that scheme in the light of the possibilities and problems that it raises. They do not "generate" multiple schemes. They do not need to "model" a variety of proposals in order to come up with one that is appropriate.

Autonomy or isolation of the individual

Our study of practitioners confirms that most hold to one or several of the following understandings of the role of the computer.

(i) The computer is equipment that demands concentrated attention. Its use leads to isolation from other aspects of office practice.

(ii) The computer is a tool that enhances the capabilities, and thus the autonomy, of the user.

(iii) The computer is ubiquitous technology. The computer fades into the background-it's just part of the furniture, part of the equipment that you use to get the job done.

(iv) The computer is a window to information and data via electronic mail, on-line catalogues and collaborative environments.

(v) The computer increases our dependence on a technological matrix, including our dependence on those who are responsible for delivering the technology.

These positions are not mutually exclusive. Practitioners tend to fluctuate between these various attitudes towards technology. Each will be discussed in turn.

(i) The perception that computer use can lead to isolation from other aspects of office culture has a number of origins. Practitioners find that there is a level of engagement when working at computers that may be different to working with pen and paper or at a drawing board.

When you're at a drawing board you get distracted more easily than when you're at a computer. It's just because you look up and have a look at what other people are doing, whereas the computer somehow has this effect where you can stare at the computer for ages ... I think you need more attention because you're not just drawing a line. You're thinking about how long this line has to be, and you're thinking about the X and Y coordinates continuously.

Drawing boards are "more physical" than computer terminals, you are also working with a larger surface. One strategy that practitioners have implemented in an attempt to preserve some of the "drawing board office" qualities is to have display screens that are large enough for two or three people to sit around. Another is to avoid creating a work pool of CAD stations by distributing the computers throughout the office. Interestingly, the reduced work surface does not seem to be a problem for individual users, even though they must pan and zoom to negotiate their way around a drawing.

Also at play in user's perceptions of computers *as a source of isolation* is the '60s and '70s image of the automated office as a soulless environment where people are there to "serve" the technology. This mainframe aesthetic is gradually being displaced as computing technology becomes commonplace. But residual fears remain. This is particularly true of those practitioners that are not yet participating in the use of advanced IT.

For a lot of lay people the idea of a computer is completely tied up with the idea of cold, hard-headed rationalism, and this actually prevents a lot of people from accepting or using the technology because they would consider accepting computers to be the same as accepting a cold, hard-headed, rationalistic approach to life. If we could break down the concurrence in people's mind of computing and rationalism, a lot of interesting things could happen with computers in practice.

(ii) Computers have the potential to enhance the autonomy of the designer in a number of ways. Computer applications can extend the skills of the designer.

You become a secretary, an accountant, a graphic designer because you're in the business of selling information and you have to present that information professionally. The level of information presentation is very high.

I couldn't possibly perform a design role without the full range of technology, I can no longer draw with a pen and pencil. Anything that I do in the design area is either in my head entirely or it's entirely on the screen. For me it's been wonderful: I could not sketch in 3D; to be able to model certainly enhanced my design skills.

Computers are eliminating middle management, thereby enhancing the autonomy of those who are left .

There are two schools of thought: there are the professionals that resist doing those sorts of tasks; and there are those that embrace it because *it allows you to do what you want to do without having to transfer the information to somebody else.* I think, like most organisations, we're probably pushing out the paper shuffle of middle management. People who cannot add knowledge are just disappearing.

Finally, computers appear to facilitate the execution of mundane tasks, freeing up the designer's time so that they can concentrate on other activities.

I do not think that design has become more complex than it ever was, but I do [think] that computers allow us, by taking care of the complex tasks, to concentrate on other ones.

Of course, some of these tasks are outside of the traditional areas of architectural expertise, and now include page layout, formatting and IT trouble shooting.

Computers are still considered to have an obtrusive presence in architectural practices. This can be both a positive and a negative phenomenon. On the one hand lack of familiarity with the technology can interfere with designing.

One of the problems initially when you start working with CAD is the way that the information is input compared to the way that we design. Design is essentially a right brain, pattern making activity and the way that we input, even with a mouse, tends to be left brain dominated because even with a mouse you're doing keyboard things and certainly in the initial stages *until that becomes fully automatic* what tends to happen is that you're in a right brain spatial mode and you have to switch to a left mode to input information.

On the other hand computers can be seen as special, and access to the technology may be regarded as a privilege.

Today we are talking from the "inceptional" end of CAD. Ten years down the track it may be completely different, where CAD operators and designers may feel like data processors feel today. At the moment there is a novelty associated with CAD where people feel they have achieved if they end up on a machine.

(iii) As familiarity with the technology grows computers are becoming part of the day to day life of design practices. However, the involvement of aspects of architectural practice in an anti-technological romanticism may mean that practitioners follow rather than lead in the appropriation of information technology.

A lot of architects don't like the technology of their practice (even drawing boards). I think we need an understanding of the role of technology, and in the past architects have been pretty bad at catching up.

(iv) The notion of the computer as a window to information is at the forefront of predictions about the future but, for the moment, is largely unrealised in practice.

I do not think that we are barraged with more information than in the past, but the opportunity is there to access information and it is just not being presented. I think it is insane that you cannot dial up a database and find all the different types of glass available on the market.

To date there are only a few companies that have developed databases of information relevant to designers. Some practices are using electronic mail to communicate between offices in different cities but these practices are the exception rather than the rule.

(v) As architectural practitioners incorporate IT into their firms they become increasingly dependent on both the technology, and upon those who supply, maintain, and coordinate the use of that technology. This dependence can be unsettling.

I am more removed from the process than I otherwise would have been; more dependent on others than I would like to be.

Many practitioners have actively resisted being placed in a position of dependence on technology and "technocrats," by insisting that architectural personnel take on responsibility for the technology rather than employing technology specialists.

IT and emerging management practices

The management practices which have evolved as architectural offices embrace IT stand as testimony to the weight of existing norms and practices. The transfer of "architectural" values and modes of operation are evident in phenomena such as the tendency of many offices to favour "studio" models of training for IT, and the reluctance of many offices to employ dedicated non-architectural technical staff. Our survey revealed interesting trends emerging in the following areas:

day to day management

IT selection

training for IT

customisation

Day to day management

The introduction of IT is changing the way in which architectural practices operate. This is particularly the case in relation to CAD. The most intensive use of CAD to date has been in the area of documentation. It is not surprising then that this is the area that has generated new management tasks. New management tasks common to most practices using CAD include the following.

(i) *The scheduling of drawing production*

With CAD drawing elements can be re-scaled, and detail can be added to them. It often makes sense, therefore, to complete smaller scale drawings (1:200s, 1:100s) before more detailed drawings. Furthermore, base drawings can often be directly referenced so that information is drawn once only rather than duplicated across drawings. This can be of considerable assistance in ensuring that modifications are reflected throughout the entire documentation.

(ii) *Scheduling the provision of information*

The accuracy of CAD can impose a requirement that accurate information about a proposal be supplied from the earliest stages of the documentation process. Inaccuracies that formerly may not have been picked up until construction had commenced show up in the documentation phase. The change that this introduces is that designers may now have to specify information earlier than they did using manual methods. For example, a designer may have to indicate the precise dimensions of the site or the building envelope at the sketch design or development application phase.

(iii) *The maintenance of office standards*

Critical to the effective operation of CAD is the establishment of appropriate layering standards, title blocks, libraries of elements and file structures. A coordinated approach is required to avoid idiosyncratic systems of operation emerging between CAD operators. The need for coordination is more important where there is the customisation of menus and macros.

(iv) *Coordination with other offices*

Apart from the difficulties involved in translating files from one CAD program to another, the principal difficulty in sharing CAD files is that different practices employ different layering standards and naming conventions. Furthermore, there are potential difficulties associated with establishing protocols for data transfer between offices.

(v) *Maintaining backups and archives*

Instituting reliable backup procedures is critical to the success of any IT based activity. This can be a difficult thing for practitioners with limited exposure to IT to grasp.

(vi) *Tracking versions of files*

Different users may independently make changes to a file. Individual users may store several versions of a file. Keeping track of the latest version of a file is a significant management task. There are several software packages available that assist in this.

(vii) *Controlling access to equipment*

In many practices terminals are shared. Furthermore, determinations have to be made as to which projects and which parts of projects are undertaken on CAD.

(viii) *Technical support*

Some larger practices consider it necessary to employ a dedicated technical person ("systems manager"), usually with a technical computing background. The small and medium firms want to avoid the situation of having to employ dedicated technical personnel. They continue to rely on vendors, bureaus and their own knowledge for technical support.

In some practices the incorporation of these management tasks can change the way work is undertaken in those practices. For example, one of the practitioners interviewed regarded the management changes as indicative of a transition from a craft based industry to a production line. In some practices the management of drawing production already exists as a distinct task (independently of the introduction of CAD).

Designers are designers and then there's another breed of people called design managers. They're the people who have to help produce the project.

Where this is the case we expect that the management of the production of CAD drawings would simply become an extension of the "design management" function. Finally, small practices may assimilate the changes required without dramatically changing the way that they operate.

In all but the smallest practices the introduction of CAD has entailed the nomination of a "CAD manager." The qualifications and status of this person within a practice varies considerably. The CAD manager may be appointed from the ranks of designer or design manager, or they may simply be the firm's most proficient operator. In most cases this person is expected to combine the role of "CAD manager" with their original function.

IT selection: the emergence of standards

There is an emerging sense amongst practitioners that the use of computers in the industry has its own momentum. Making technology related decisions is not a matter of "rationally" analysing the nature of the practice and the various hardware, software and training systems available. It is rather a matter of deciding

what is the standard system in use in the industry. Such standards are often "de facto." They emerge within the tacit conventions of praxis that are the results of persuasive marketing, products that are general and robust, and a culture of use that develops where practitioners can share their understandings of the systems. Hardware is subservient to software in this regard. By always selecting standard software the practitioner does not have to research what different vendors have to offer. Practitioners are in a position to appreciate what the software can do for them as others are already using it. They expect to be able to gain such an appreciation without being immersed in technical detail. The industry tends to consolidate its expertise and practices around particular software, for example, AutoCAD.

Many practitioners recognise that these "standards" are not necessarily the best systems available. Some practitioners consciously depart from the norm selecting software that they feel to be appropriate to their own particular practice. Others adopt the "standard" to be compatible with other firms or because of the quality of support (maintenance, training, troubleshooting) available.

Training

Training is a deliberate intervention into practice to accommodate the changes experienced with the introduction of new technology. Of central concern to practitioners is the issue of IT related training. This reflects both the state of the software and the degree to which the profession has adopted IT. The industry is in the process of building up a pool of professional and technical staff trained in the use of the technology. The attitude of management towards training can be critical to the successful implementation of IT.

Practitioners are buying into two traditions with regard to training: (i) the business model of short formal training courses, and (ii) the studio based model with its design orientation and emphasis on tacit understanding. The business model is mainly adopted by the larger practices for training in areas such as word processing, spreadsheets and technology related management issues. This short formal course training may be provided through external courses or courses run in-house. Apart from short initial training courses provided by the CAD vendors, "studio" based training is the preferred option in relation to CAD. Many practitioners feel that CAD training is only really effective in the context of working on a real project. Most, however, are critical of leaving inexperienced operators to their own devices. "On the job" training coupled with support from experienced operators is considered to be the most effective approach.

The fact that the industry is currently in short supply of trained personnel creates problems. While there is some concern that it is difficult to retain trained staff, many practitioners take the view that it is short sighted not to train people for this reason.

If you train people they recognise that you have the right attitude.

Some highly trained operators have been able to demand high salaries because such expertise is in short supply. This is particularly the case with the use of CAD to develop photo-realistic renderings. Training is clearly an issue when it comes to selecting hardware and software. Some practices make exclusive use of Macintosh computers, which are understood to require little training, and to avoid confining expertise to a few experienced operators.

The dominant value of the architectural office is an emphasis on design. Architects have been reluctant to erode the standing of design values through an emphasis on technology. This has had both positive and negative implications in terms of the training of personnel. In many cases it has meant that training of both operators and other relevant staff is inadequate. Rifts have been created between design, management and technology personnel. On the other hand, the values of the profession have remained intact. The operator with a good knowledge of construction or who is capable of using CAD as a design medium is highly valued. Simply gaining computing skills, however, does not ensure increased standing for the individual within the profession.

Customisation

The attitude of practitioners towards customising their own software varies dramatically. On the one hand it is recognised that customisation can be expensive, and there is the risk of developing idiosyncratic systems which make the transfer of files and expertise difficult. However, in many cases it has been necessary to customise systems in order to make them more productive. Without customisation some systems are too complex to use. The command set may be too large or difficult. Customisation can simplify the way that files are organised, or drawings are layered. Customisation may also be necessary to save operator time and to minimise repetitive tasks.

Two conflicting views emerge with regard to customisation: (i) that it is necessary to customise in-house; as opposed to (ii) that you should wait until third party products are available-that it doesn't pay to be "leading edge." It is common for in-house developments to be shared amongst practitioners through user groups (Sidhu, 1990).

Many practices undertake some system development and/or enhancement work, mainly writing macros and customising menus. Few practices, however, have a full time staff member dedicated to system development and enhancement work (Sidhu, 1990, p.36).

Praxis and the Future

The praxis model suggests that our practices are carriers of culturally defined metaphors. These metaphors shape our attitudes towards the future. In assessing the future role of computers commentators invariably invoke some overriding metaphor of what the computer is-a disparate set of databases, a form of intelligence, a communications tool, a medium. Out of each of these metaphors arise scenarios that accord with the metaphor-the future lies in integration, intelligent assistance, collaborative design systems, or an adventure in a multimedia cyberspace.

Integration

"Integrated CAD" involves the pursuit of a single building model from which practitioners such as engineers, quantity surveyors, and facilities managers can automatically extract the data that they require. Vendors and researchers emphasise the importance of this development.

This is where it's all going-getting my system to talk to the consulting engineer's systems to talk to the client's real estate agent's system, his property manager... It's all about communication, communication protocols and data protocols-this is where the excitement is.

The major prediction for the future from one consulting engineer was of

huge integrated databases and whole buildings designed with one system. Most have not come true and we are still predicting them.

Fully integrated CAD so far appears to be elusive in practice.

We're currently experiencing that problem with the children's hospital where we're using a lot of consultants with different CAD systems.

There's currently no way of transferring 3D-we've just had a job where it would have been very nice to get the engineer's 3D.

According to one consultant

Even with our client base we deal with about five different CAD systems.

There are problems with the idea of full integration. No matter how comprehensive is the building model there is always a need to augment that model or to change the way that the building is described (Rooney, 1987). For example, the issue of whether dimensions should be taken from the outside walls, inside walls or the centre lines of walls will vary according to who is using the model and for what purpose. As a further example, the definition of floor to ceiling height changes where there is a light well passing though the floor.

It's a myth this full 3D model in which everyone whips in and takes data out of it, but a disintegrated model is quite feasible and I think that's the way we're going.

Responses to these kinds of problems fall into two categories. On the one hand there are those who see lack of integration as a problem with the initial description. The CAD system should be modified so that it forces the user to supply the required information at the outset of the entry of the building model. For example, the CAD description used to produce drawings for building development approval should also include information about the type of floor material, which may be necessary in the calculation of costs later on. According to this view the CAD system should be modified so that the CAD user has to specify the information about materials at the outset. As a second response the facility can be provided in the CAD system to allow a user to specify the relevant information or to tag entities (such as floors and walls) with such information only at the relevant stage of the design and documentation process.

The advantage of the second approach is that it recognises that within the construction industry sophisticated communications conventions are already in place. Architects, builders, engineers and quantity surveyors are trained in the interpretation of working drawings. Working drawings do not constitute a three dimensional *model* of a building. They are slices through the building that are sufficient to communicate to the relevant professionals the information that they require. There are strategic moments when it is appropriate for the designer to make decisions about materials and finishes. Designers should not be forced to commit themselves to such specifications prematurely. Rather, CAD systems should allow the relevant professionals to specify and extract the information that they require as they require it.

A similar problem to the timing of decision making arises in relation to the transition between conceptual design and working drawings. Some designers have found computer based 3D modelling to be useful for conceptual design. The traditional approach to supporting such exploration has been to allow the designer to construct building models from standard and pre-defined elements such as walls, floor slabs, doors and windows in such a way that the "model" can be automatically converted into a set of working drawings. The problem here is that designers do not normally work with such "primitives." Abstract three dimensional graphic primitives such as cubes and spheres are more appropriate to work with, and provide greater flexibility, at the sketch design phase. "Conversion" of such three dimensional models into working drawings may involve taking slices through the model as an underlay for the production of plans and sectional working drawings.

A corollary to integrated building models is the view that it is possible to create data exchange standards that will make possible the transparent transfer of data between different CAD systems or specialised application programs. The problem with this view is the same as the problem with the assumption that we need integrated building models-different representations are good for different purposes. To hold that all applications of a model should be based on the same underlying representation, or should be able to be converted into a "standard" representation, would be to hold that all applications programs have similar data requirements. Such a position denies that differences in the functionality of applications are significant.

At the moment it is impossible to communicate between systems even with DXF [a common data exchange standard].

The difficulties that participants in the STEP project, a project aimed at establishing a standard representation for CAD conversion, have in agreeing on a common representation is testimony to the efficacy of different representations for different purposes.

The moment that you try to create standards is the moment that people try to change them but there would be a lot to gain.

The belief in integrated CAD also underlies certain misgivings about the technology-that the computer will be pervasive and indispensable, it will be a tool of total and integrated control of the design, construction and management of the building, and eventually of all the players in the design and construction process. The greatest power will reside with whoever controls the database.

The impact on the built environment is going to be enormous-it's going to come through integrated databases. The design professional will leave the contractor behind in this regard.

Intelligent systems

The goal of creating "intelligent" systems permeates thinking at many levels of computing technology. At its most extreme it has led to attempts to uncover algorithms for design or algorithms for creativity (Simon, 1975; Stiny and Gips, 1978; Stiny and Mitchell, 1978). The initial enthusiasm within the profession for *expert systems* follows a scenario emerging from the metaphor of computers as "intelligent systems."

Information exchange means by default that you have access to a lot of information. Manipulating it is a province of expert systems. Expert systems haven't taken off anywhere near where people thought they would, but that's partly because you need an environment rich in data.

Attempts to convert scanned documents (raster drawings) into CAD formats (vector drawings) provides an instructive example of early attempts to apply "automated intelligence" to solving geometrical problems. Teicholtz reviews the state of the art of scanning technology.

Every year someone says that accurate raster-to-vector conversion is only a few years away, and while this software is maturing, a perfect "blackbox" conversion may never exist. … The ineffectiveness of early "vectorizing" software turned some potential users off, but then a new concept emerged: scan overlays. (Teicholtz, 1991, p.55)

The "problem" of raster to vector conversion is one of converting a matrix of pixels (dots) into lines and arcs. Automatic conversion typically yields vector drawings made up of a great number of lines that fail to reflect the geometric construction of the original drawing. As Teicholtz points out much effort has, and continues to be, expended on improving automatic conversion techniques. The alternative is to use the raster drawings as base drawings within CAD systems. They can simply be stored in raster format and be used, for example, as base plans for furniture layouts. Alternatively they can be converted into vector format by manual tracing on the computer screen. The advantage of the latter alternative over automatic raster to vector conversion is that the user is in control of the geometric entities created.

It is significant that the notion of "scan overlays" emerged as a "new concept" in the wake of earlier (disappointing) attempts to automate raster-vector conversion. The pursuit of "intelligent" systems is often construed as being a harmless, if not imperative, exercise. It is becoming increasingly evident, however, as vendors and researchers fail to deliver the promised "intelligence," that the pursuit of such systems has resulted in the neglect of the often competing requirements for the provision of facilities that allow the user appropriate control. For example, if the orientation is towards creating "intelligent" systems then emphasis will be placed on creating *the right* database structure. If, however, the orientation is towards allowing the user to interactively control the process of constructing and manipulating databases then the environment which the user is exposed to will be completely different. In the case of the "intelligent" systems approach the user is primarily required to manipulate parameters. In the absence of "intelligent" systems the user must be provided with facilities for defining data and constructing relationships between elements of that data.

Notwithstanding the difficulties there is optimism amongst practitioners about the ultimate feasibility of expert systems.

I think a lot of the stuff which has been done is nonsense, but we'll get there eventually.

They're going to happen but the results are going to be a fair way away because of the complexity, especially considering the fact that we as a profession can't agree on a set of layering standards. An architect makes a snap decision that would require an expert system to sort through hundreds of variables, and the data base has to be up to date. An architect might not make the correct decision but he makes it instantaneously taking all sorts of abstract concepts into account.

We could probably come halfway, but I do not think we can replace a designer with a computer. They will eventually be very helpful in the decision-making process. Computers are good at number crunching and storing information, and the extent of its use will be as a code checker.

Collaborative IT

The computer is being used increasingly as a communications device. The metaphor of the computer as communications tool provides the impetus for recent developments combining the computer with electronic communications. Electronic communication involves the exchange of digital information across a computer network. Information held in one computer user can be transferred to any number of other computers. This exchange can be instantaneous (synchronous), can include various types of media (text, graphics, audio, video), is possible across different makes of computers, and can be as efficient between international sites (wide area networks such as Internet) as it is within a single office network (local area networks such as Ethernet or Appletalk).

Computer-supported collaborative work (CSCW) and computer-mediated collaborative design (CMCD) builds on the potential of electronic communications to allow individuals at remote locations to work together. Technology is already in place to enable the real time transfer of high resolution images (such as CAD graphics and video) across existing local, regional, national and global telecommunications networks. Such developments make it possible for multiple users in remotely located offices to interact in real time while using the same item of CAD software. There are several possible scenarios: interactive access to multimedia databases including promotional examples of successfully completed buildings, details of current work in progress or potential development sites, "best practice" information on innovative construction technologies, illustrated industry standards and CAD databases of standard details; electronic couriering of large text or graphic files such as specifications or entire CAD models; videoconferencing and basic telephonic communications entirely via the computer workstation; designers working directly with CAD, supported interactively by specialist CAD operators; the "virtual" design team or site meeting; and a "virtual" desktop comprising a wide range of CAD applications, available and running over a network of different machines, with each machine supporting the specific application to which it is best suited. Computer-supported collaborative work is implicated in the re-shaping of the geographical and organisational structure of a practice and its client and consultant base.

As yet practitioners do not make extensive use of computer-mediated collaborative work, but many can see the potential.

We're going to need exactly that in a couple of months with a job that we are doing with a large city office but it's not available so we're going to have to get in our cars and drive in-and I resent that.

The grounds for optimism about the effects of extensive electronic communications reside with the success of the fax machine.

Can you imagine how we used to live without a fax? The challenge is not the immediacy of the updates but how you manage the distribution of them.

But there are reservations about even the feasibility of widespread use of electronic mail.

There is no doubt that fax make it much easier to get hard copy from one place to another but the use of electronic mail in most architectural offices is non-existent, to make it work properly you would have to have a large organisation with a high percentage of workstations to employees or it's self defeating. The exchange of information between various disciplines (eg. the architect and the engineer) is almost a non-event because nobody has the same system, even if they have the same system they don't have the same hardware or the same disc or tape drive.

There are two sets of problems that emerge from the scenario of computer-supported collaborative work. First, the realisation of this opportunity is pursued from the point of view of traditional CAD "problems." The key issues are seen to revolve around the control of consistency and data continuity (whether to have a centralised or distributed data storage and processing resource), on replicating the full richness of face-to-face communication (such as having visual and audio links, and working around a common desktop), data exchange standards, and auditing (such as ownership of ideas and copyright). In each of these problem domains the general approach is to encode a set of procedures that accord with existing design practice. Data consistency is seen as a security problem to be solved through more effective control (such as file locking and user access privileges), face-to-face communication is seen as a problem of *channels* to be solved by including audio and video exchange (with communication protocols similar to CB Radio or aircraft control), data exchange is seen as a *standards* problem to be solved through a common building description for the industry, auditing is seen as a *quality assurance* problem to be solved by logging and recording details as changes are made (details including the user responsible for the change, when the change was made, and who agreed to the change).

This approach is not dissimilar to the one applied in the development of CAD itself, where the intention has largely been to encode a set of procedures that accord with manual drafting practice. In every case the major difficulty would appear to be in prescribing the full range of uses for a particular feature of the computer system. Data exchange standards are very useful, but the search for a single industry standard denies the value of features of individual CAD packages that makes them attractive. Total data consistency would appease most CAD managers, but may be an impractical goal in the context of the dynamics of design. Wherever standards, protocols, controls, checks and systems are implemented, there are particular instances where such procedures do not readily apply and where individuals will therefore seek to subvert and undermine those procedures.

The second set of problems pertaining to computer-supported collaborative work recognises that electronic communication will rapidly become ubiquitous. Rather than attend primarily to standards and protocols, the issues of concern then become issues related to the integration of this technology within a constellation of praxis. How might practitioners make effective use of electronic communications?-not to replace existing modes of communication (such as surface mail and face-to-face conversation), but to augment existing modes of communication (to work away from the conventional office, at home or interstate). How will the practice of design engage the technology? How will it be used and what new design services will it enable? What new insights to design practice will this shifting emphasis on communications bring to light?

Multimedia and Mass Media

There is a growing sense that the computer and the mass media are merging. The metaphor of the computer as medium, in the sense meant by Marshall McLuhan, has been strongly promoted by computer systems developers such as Kay (1991), and this conception is influencing how some design practitioners see their firm.

Computerised communications networks are now assuming many of the attributes we normally associate with the mass media-radio, television and newspapers. We can characterise the mass media as what becomes of writing and the pictorial arts under the influence of mechanical and electronic reproduction-or mass production. The mass media are concerned with *reproduction.* Information is generated, copied and reproduced many times over. It is also concerned with *dissemination*-information is distributed widely through media networks. The mass media also involve *editorial control.* All information received is not

distributed indiscriminately but is moderated, sorted and censored by editors, editorial boards, or referees. The mass media are also *ubiquitous*. Their artefacts are to be found in homes, work places, and as part of the landscape as billboards, video displays, and radio and television broadcasts picked up on car radios, walkmans and portable televisions. The mass media are also *public*-information is generally distributed indiscriminately, or to "news groups," rather than used privately. Some aspects of the mass media display the property of *portability*-products of the media (newspapers, magazines, portable radios, etc) can be acquired and carried around by individuals. The mass media are also *ephemeral*-the content of the mass media often has a short life, perhaps it is archived or repeated, but generally it is never to be revisited (newspapers have a life of one day, radio broadcasts a life of several minutes). Finally, the mass media are *impressionistic*. The mass media, at their most characteristic, generally trade in quick impressions rather than precisely crafted and accurate information.

The confluence of computerised communications and the mass media brings about an entity with certain emerging characteristics. The mass media have been interactive for a long time-with letters to the editor, talk-back radio, and the broadcasting of home videos on television programs-but now there is the possibility of sophisticated synchronous (real time) interaction through computer networks-such as "on-line bulletin boards" and Teletext (Rafaeli and La Rose, 1993). The electronic mass media have the potential therefore to be *highly interactive*. The electronic mass media now rely substantially upon computer networking. Computer networks, telecommunications and media networks are merging (Weiser, 1991). The new mass media also increasingly rely upon digital data manipulation-desktop publishing, digital image capture and manipulation, multimedia systems, talking books, and the use of CD ROMs (digital compact disks).

According to some commentators, the mass media traditionally operated as a "one-to-many" form of communication-one source, many recipients. The new emerging mass medium is "many-to-many"-any individual can instantly communicate with another individual, or to a group. As such, the new mass media are thought to have the potential to re-vitalise the democratising power once accorded to newspapers and broadcasting (Rheingold, 1993). As one practitioner put it:

information equals power; until such time that enough people have that information or access to it; then the power ceases.

Electronic communications and the mass media are also implicated in new conceptions of the computer as providing a *total immersion environment* (Helsel and Roth, 1991; Rheingold, 1991). Experiments in "virtual reality" are thought to herald a possible future in which our senses are plugged into a virtual world of information. This world has features of the physical world. It is said that we will enjoy the physical sensation of moving through simulated physical environments (buildings and landscapes), move through information as though it were transparent to all of the senses, and interact with other people as though we are with them, and assuming whatever form suits us. These scenarios implicate design practice. Benedikt (1991) suggests that there will be specialised "cyberspace architects" who deal with space no less that do traditional architects, but their medium will be information.

As this aspect of computing is new to practice there was very little understanding amongst survey participants of what it entails. Though for one practitioner interviewed the media angle pervaded the whole practice. This was mainly in the area of the promotion of early design proposals.

So we've been a mixed media communications company as much as an architectural firm. We go from the dream making end of it all the way.

Multimedia is a fundamental part of our practice-it's as important as all the other architectural processes and I think it's something that architects have really sold themselves short on. You have to communicate in the realm of concepts and ideas competently … The truth is that there's so much media around that you can muster to give full expression to your ideas, and these decision makers are subjected to communication like that all the time now, everybody gets presentations on videotape-if you're not competent in those communications fields you're going to be stuck in a sort of paper technological field.

Summary

We have favoured the praxis model for our analysis of the experience of practitioners. According to this model the members of a firm are players in an interconnected whole that involves people and their relationships (organisational and informal work relationships), ways of working, technologies and systems of equipment and their interdependencies. By accepting this interconnected whole as the starting point in understanding the firm we are able to pick up on experiences that might go unnoticed in a strict systems or analytical approach. From our study it is evident that there are different strategies through which computers are embraced, or even rejected, by practice. Amongst firms who accept computers there is the strategy of substituting one component (an item of equipment or a task) in the practice for another, such as replacing drawing boards with CAD systems. There is also the strategy of restructuring the firm's activities to carry out traditional tasks in an innovative way, such as turning the documentation of projects into a database management exercise. There is also the strategy of extending existing services, such as moving into the media production business in some way. Whatever strategy is adopted, the introduction of computer technology brings about changes in how the practice is conducted, the nature of the market place, and the role of the individual practitioner. We also discussed some of the management implications of the introduction of CAD and some major metaphors through which practitioners construct scenarios of the future.

These include the use of the computer as heterogeneous equipment to be integrated, the computer as intelligent assistant, the computer as a communications device, and the computer as mass media. Recent developments in computer technology ensure some currency to the last two metaphors, which will soon make their impacts felt in the way practices see their future.

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References

Architectural Record (1984) Round Table: Computer use in the small architectural firm, *Architectural Record,* May: 39-53

Architectural Record (1990) Beyond Computers as Pencils, *Architectural Record,* November: pp 28-31.

Atkin, B. and Gill, M. (1986) *A Study of CAD in the U.K. Construction Industry,* Construction Industry Computing Association, Cambridge, England.

Aungles, S. ed. (1991) *Information Technology in Australia,* New South Wales University Press, Sydney

Australian Bureau of Statistics (1991) *Architectural Services Industry, 1987-88: Supplementary Statistics for Architects,* Belconnen, ACT.

Badham, R. (1991) *Computers, Design and Manufacturing: the challenge,* Australian Government Publishing Service, Canberra.

Benedikt, M. (1991) *Introduction, Cyberspace: First Steps,* ed. Michael Benedikt, MIT Press, Cambridge, Massachusetts, pp.2-25.

Bernstein, R. (1991) *The New Constellation: The Ethical-Political Horizon of Modernity/Postmodernity,* Polity, Cambridge.

Braverman, H. (1975) *Labour and Monopoly Capitalism,* Monthly Review Press, New York.

Cowdroy, R.M. (1985) *Clients' Perceptions of Architects' Performance,* Board of Architects of N.S.W., Sydney

Coyne, R.D and Snodgrass, A. (1991) Is designing mysterious? Challenging the dual knowledge thesis, *Design Studies* **12** (3): 124-131

Coyne, R.D and Snodgrass, A. (1993) Cooperation and individualism in design, *Environment and Planning B: Planning and Design* **20**: 163-174

Coyne, R.D., McLaughlin, S. and Newton, S. (1994) A survey of computers in design practice, *Report*, Department of Architectural and Design Science, Unviersity of Sydner, NSW, Australia.

Crawford and Hutchinson (1990) *A Study of Means of Maintaining and Developing Professional Competence Throughout a Career as an Architect,* Board of Architects of N.S.W., Sydney.

Cross, N. (1984) *Developments in Design Methodology,* Wiley, New York pp. 245-264

Cuff, D. (1991) *Architecture: The Story of Practice,* MIT Press, Cambridge, MA.

Darke, J. (1979) The primary generator and the design process, *Design Studies* **1** (1): 36-44

Dean, J. and Olley, H. (1988) *The Market for Architectural Services-An Initial Investigation,* Royal Australian Institute of Architects National Education Division, Red Hill, Australia.

Dill, J.C. and Pitman, J.H. (1985) Computers: Evaluate your Options, *Architectural Record* October: 45-47.

Doubilet, S. (1987) P/A Reader Poll: Computer Use, *Progressive Architecture*, **68** (8), August: 15-18

Dreyfus, H.L. (1979) *What Computer's Can't Do: The Limits of Artificial Intelligence,* Harper and Row, New York.

Dreyfus, H.L. (1991) *Being-in-the-World,* MIT Press, Cambridge, Massachusetts.

Drucker, P.F. (1968) *The Practice of Management,* Pan Books, London.

Fish, S. (1989). *Doing What Comes Naturally: Change, Rhetoric and the Practice of Theory in Literary and Legal Studies*, Duke University Press, Durham, Southern Carolina.

Forester, T. (1989) *Computers in the Human Context: Information Technology, Productivity and People,* Basil Blackwell, Oxford

Foz, A. (1973) Observations on designer behaviour in the parti, *Design Research and Methods* **7** (4): 320-323

Gadamer, H.-G. (1975) *Truth and Method,* Sheed Ward, London.

Goldman, G. and Zdepski, M. (1991) Using computers before the working drawings, *Progressive Architecture* January: 131

Gomez, P. (1983) *Architecture and the Crisis of Modern Science,* MIT Press, Cambridge, Mass.

Gordon, D.E. (1989) When will CADD come of age?, *Architecture,* December: 95-99

Gutman, R. (1988) *Architectural Practice: A Critical View,* Princeton Architectural Press, New Jersey

Harris C.L. (1989) Office automation: making it pay off, *in* Forester, T. (ed.) *Computers in the Human Context: Information Technology, Productivity and People,* Basil Blackwell, Oxford pp. 367-376.

Heidegger, M. (1977) The question concerning technology *in* Krell, D. (ed.) *Martin Heidegger: Basic Writings,* Harper, San Francisco. pp.287-317.

Heim, Michael (1993) *The Metaphysics of Virtual Reality,* Oxford University Press, New York.

Helsel, S.K and Roth, J.P. (eds) (1991) *Virtual Reality: Theory, Practice and Promise,* Meckler, Westport, Connecticut.

Hillier, B., Musgrove, J. and O'Sullivan, P. (1972) Knowledge and Design, in Mitchell, W.J. (ed.) *Environmental Design: Research and Practice,* University of California, Los Angeles.

Jackson, D. (1993) The future for architecture: a new blueprint for Britain, *Architecture Australia,* May/June: 72-73

Jay, M. (1984). *Adorno,* Harvard University Press, Cambridge, Massachusetts.

Jones, B. (1982). *Sleepers, Wake! Technology and the Future of Work,* Oxford University press, Melbourne

Kay, A. (1991). Computer, networks and education, *Scientific American,* September, pp.100-107.

Kindon, D. (1979) *Marketing Architectural Services, Part 1: The Marketing Audit,* Royal Australian Institute of Architects Information Division, Manuka, Australia.

Kish, E. (1991) CAD and the Profession, *Progressive Architecture,* May: 142-143

Kranzberg, M. (1989) The Information Age, in Forester, T. (ed.) *Computers in the Human Context: Information Technology, Productivity and People,* Basil Blackwell, Oxford. pp. 19-32

Kuhn, T.S. (1970) *The Structure of Scientific Revolutions,* University of Chicago Press, London.

Laurel, B. (1991) *Computers as Theatre,* Addison Wesley, Reading, Massachusetts.

Leebaert, D. ed. (1991) *Technology 2001: the future of computing and communications,* MIT Press, Cambridge, Masachusetts.

Lischewski, H. (1987) Computers: practical tips for CAD selection and management, *Architectural Record,* August.

Meyrowitz, Jushua (1985) *No Sense of Place: The Impact of Electronic Media on Social Behaviour,* Oxford University Press, New York.

Mitchell, W. J. (1987) Reasoning about form and function *in* Kalay, Y.E. (ed.) *The Computability of Design,* Wiley, New York pp. 89-98.

Olley, H. (1992) *1990 Profile of the Architectural Profession,* Royal Australian Institute of Architects: National Division, Canberra

Peters, T. and Waterman, R. (1982) *In Search of Excellence: Lessons from America's Best-Run Companies,* Harper & Row, New York.

Pitman, J.H. and Dill, J.C. (1984) Computers: the need for graphic standards, *Architectural Record* February: 23-27

R.I.B.A. (1992) *Strategic Study of the Profession,* Royal Institute of British Architects.

Radford, A.D. (1988) *Computers in Australian Architectural Practices,* RAIA Education Division, Red Hill.

Rafaeli, S. and La Rose, R.J. (1993) Electronic bulletin boards and "public goods" explanations of collaborative mass media, *Communications Research,* Vol.20, No.2, pp.277-297.

Rector, R.A. (1990) The economics of rationality and the rationality of economics *in* Lavoi, D. (ed.) *Economics and Hermeneutics*, Routledge, London.pp. 195-235.

Rheingold, Howard (1991) *Virtual Reality*, Summit Books, New York.

Rheingold, Howard (1993). *The Virtual Community: Homesteading on the Electronic Frontier*, Addison Wesely, Reading, Massachusetts.

Rooney, J. (1987) Representing objects, in Rooney, J. and Steadman, P (eds.) *Principles of Computer-aided Design*, Pitman, London pp.13-37.

Saint, A. (1983) *The Image of the Architect*, Yale University Press, New Haven.

Shugg, C. (1993) Gaining a positional advantage with CADD, *Architecture Australia*, Jan/Feb: 61-63

Sidhu, J. (1990) *The Use of CADD in Architectural Practices in Sydney*, Unpublished masters thesis, Department of Architectural and Design Science, University of Sydney, Australia.

Simon, H.A. (1975) Style in design, in Eastman, C.M. (ed.) *Spatial Synthesis in Computer-Aided Building Design*, John Wiley, New York.

Stevens, G. (1991) CAD and the Profession, *Progressive Architecture* **72** (5), May: 141-142

Stiny, G. and Gipps, J. (1978) *Algorithmic Aesthetics: Computer Models for Criticism and Design in the Arts*, University of California Press, Berkley

Stiny, G. and Mitchell, W.J. (1978) The Palladian grammar, *Environment and Planning B* **5** (1): 5-18

Teicholtz, E. (1991) Scanning the Scanners, *Progressive Architecture* (4), April: 55-57

Teicholtz, E. (1992) *Computer-Aided Facility Management*, McGraw-Hill Inc., New York.

Thompson, W. (1991) Computer techniques for making photo-realistic presentations, *Progressive Architecture* February: 39-41

US Department of Commerce, Bureau of the Census. *Census of Service Industries, 1982.* Subject Series.

Weiser, M. (1991) The computer for the 21st century, *Scientific American*, Vol. 265, No. 3, pp. 66-75.

Weiser, M. (1991) The computer for the 21st century, *Scientific American*, Vol.265, No.3, pp.66-75.

Winograd, T. and Flores, F. (1986) *Understanding Computers and Cognition: A New Foundation for Design*, Albex Publishing Corporation, New Jersey.

PART II

Computers and Change

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This report examines the changes to design practice brought about by the introduction of computer technology. We conducted an interview survey of practitioners who use computers and investigated how computerisation is affecting work skills, what kind of stresses it is imposing on the firm, how firms make decisions about computers, what are the management and organisational implications of using computers, what kind of physical work environment is produced, and what trends and research issues need to be addressed. We report on the survey here.

We report on an interview survey of how professional designers, such as architects, use computers in practice, and how computers affect practice. As with any survey we can only report upon a slice in time of the state of practice. At the time of the survey we had to explain terms such as "multimedia" and "Internet" to some interviewees. At the time of publication new terms will have gained currency, such as "the information superhighway," "World Wide Web," and no doubt others. The rapidly changing nature of information technology provides the focus of this study. The "timeless" element of our study is the fact of change in the context of information technology (IT), and how practitioners cope with it.

We began the study with three key hypothesis. The first was that the influence of computers on design practice exceeds that of other technologies. Computers become pervasive. They touch on almost every aspect of an organisation: management, public relations, clerical tasks, and in the case of design practice, documentation and design. We aimed to discover the extent of this change. Second, we also hypothesised that computers are implicated in major changes to work practices. Computers affect the way people work together, they affect attitudes, and they impinge on power structures within organisations. We wanted to discover whether these changes impose any stress on firms.

Third, we hypothesised that computing exerts only a minor influence on the activity of design itself (or design decision making), other than in areas with a substantial engineering orientation. However, computers exhibit many indirect impacts on design by affecting designers, changing the dynamics or organisations and changing the physical work environment. Inevitably computers bring with them the imposition of a new culture that indirectly affects design. Furthermore, the promises, threats and possibilities represented by computers unsettle attitudes to design.

These hypotheses were mostly confirmed, and in the process we discovered some fresh insights into the way computers are implicated in the changing nature of design practice.

The survey was designed to test our hypotheses, that originally appeared in an article published in *CAAD Futures* (Coyne, 1992). The results of the survey may assist in accounting for the difficulty organisations experience in making decisions about personnel, capital and training relating to computing, and assist research groups in directing their efforts.

Our survey builds upon the work of others. Although considerable attention has been given to the impact of computer use on clerical workers (Otway and Peltu 1983; Turkle 1984; Wainwright and Francis 1984; Long 1987) there has been little in the way of formal studies of the impact of computers on the attitudes and work practices of designers. Some of the factors motivating computer use in architectural practice are discussed by Radford (1988), Radford and Stevens (1987), Stevens (1989) and Radford and Coyne (1989). Helpful summaries of the implications of computing in general from a social science perspective are provided by Kling and Iacono (1988), Danziger (1985) and a compilation of articles by Forester (1989). Gutman (1988), Cuff (1991) and Olley (1992) indicate the way that the profession of architecture is changing in general due to technological and other pressures. There are also many quantitative surveys of the extent of computer use in practice. Our survey is qualitative, focussing on the influence of computing on the work practices and interests of designers. In our reporting in this article we present quotes taken directly from the interviewees in support of our arguments, rather than focus upon numerical analysis of responses to each question.

We put some 54 questions (with sub questions) to 29 practitioners from architectural and engineering practices and CAD consultancies during intensive face-to-face interviews. The majority of practitioners were from architectural firms, but we also wanted the scope of the survey to be representative of the changing forms assumed by practice under the influence of computers. The majority of the practitioners interviewed were involved in the day to day management of CAD and IT. Some were dedicated CAD or systems managers. Others combined CAD/IT management roles with design or drafting roles or with more extensive management roles within the firm. One of the interviewees was a designer who made extensive use of IT but was not involved in the management of IT, others were involved in the strategic decision making in relation to CAD and IT but not with the day to day management. All but five of the practitioners had been involved personally with computers for over five years.

We structured the survey under four major areas of concern: (i) changes in the workplace-the extent of change, how practitioners cope with making decisions about computers within a climate of change, how computers change work practices, (ii) the management implications of using computers, (iii) the character of work spaces occupied by computers, and (iv) the trends, ideologies and research agendas set by computers in the workplace. The pattern we followed in the interviews was to suggest a series of propositions about computer use, to which we invited a response, which in turn solicited further insights from the practitioners. We follow this pattern in the reporting in this article.

Changes in the Workplace

Computers clearly introduce substantial changes into the work place, though practitioners were ambivalent in their reporting of the change. The majority of practitioners attested to changes in the skills of the designer due to computing. Half of those who attested to change reported that the changes were minimal.

Several changes were reported. It seems that computing (particularly CAD) has brought to light new economic considerations that practices did not have to address previously. Practices have had to address the economy of using CAD-using CAD for what it does best and less expensively. A further change is that a new sense of team work develops around CAD. CAD also enables some firms to diversify in particular ways. Some firms were diversifying into computer-related areas such as desktop publishing and audiovisual

work. One firm reported that they were able to charge larger fees for desktop publishing than for design. A further change is that with desktop publishing the production of text documents has assumed greater importance, with some firms employing a graphic designer. Other areas of diversification include: facilities management, audiovisual and graphic work, 3D computer modelling, shadow studies, documentation only services, "selling knowledge" about a particular building type through customisations to CAD systems, software development, consulting on CAD, and training. Most practitioners did not think that computing had substantially affected design-only presentation and documentation.

For the individuals interviewed the changes were more pronounced than for the firm as a whole. Some of the interviewees had moved from more traditional design and drafting roles into CAD management. The change was often dramatic. There are those who are no longer involved in design and those who think that they can only design with "the full range of technology." On the other hand, some reported that their design skills hadn't really changed. They were just working with different media. Some practitioners reported that the technology detracted from their design skills, others reported that their design skills were enhanced.

These reports of change came largely unsolicited in the interview. However, we were also interested in testing our own assessment of where change may lie.

The Relationship Between Professional and Support Staff

We asked about the change to the roles of the professional designer and manager in relation to what were formerly exclusively secretarial or administrative tasks such as typing, communications, filing and simple accounting. Some of the practitioners thought that the relationship of professional staff to administrative personnel had been restructured. Most of the practitioners said that they now carried out what were formerly administrative tasks. Most also said that they had observed this with others in the firm as well. In some cases this change had led to a reduction in administrative staff. In some cases the role of administrative staff had been extended. One of the practitioners from an engineering firm stated that the number of support staff had actually increased because the firm now produced more information of higher quality. The quality of documents was also important to one of the architectural practices, which asserted that "every document that left the office should be desktop published." The administrative assistants typed the material and then passed it on to graphic designers who did the layouts. A minority of practices said that designers should be designing and that other tasks should be left to support staff. According to one practitioner:

> We don't employ secretaries or typists. Previously we would have clerks [for filing and typing], technical people and professionals. That doesn't exist any more. We have administrative people and technical professional people. I type all my own words, I maintain my own budgets using spreadsheets.

In general, the roles of "middle management" and support staff appear to be diminishing.

Viability of Small Firms

Another apparent change to the structure of practice is that computing has made small firms more viable. The majority of practitioners confirmed this view. According to one practitioner:

> Yes, the era of the back yard operator has arrived and we need no longer feel guilty about it. I know of several circumstances where two competent architects with a CAD system are doing large projects extremely competently, and I would imagine extremely cheaply. So it empowers people with the skills to be closer to whatever it is that they want to be closer to rather than hanging around a huge office full of architects.

Some thought that small practitioners can now produce work of the same professional quality as bigger practices thanks to CAD and desktop publishing.

Making Decisions About Computers

IT poses a new regime of decision-making into an organisation-what equipment do we invest in? do we rent or lease? do we buy now or wait until later? We wanted to test whether it is difficult to make decisions in this climate of change and uncertainty. Our expectation was that decision making about IT would place some stress upon organisations. In order to test how firms were coping we first asked if there were people in the firms who are sufficiently up-to-date with product availability and IT trends. The majority of interviewees said "yes." We also asked whether or not there was a shortage of expertise in the area of system selection and management in the firm. The majority of interviewees reported that there was no shortage of computer expertise. The practitioners who thought there was a shortage reported that the main shortfall was in system management.

We suggested to the practitioners that those who know most about system selection and management may be fairly junior in the firm, because energetic new employers find that computing offers a means of career advancement, and they may have had some training at university. There was general disagreement with this. One practitioners observed:

CAD's been around long enough now but it was a problem five years ago.

We asked if the decision makers of the firm consult widely and well before making decisions in relation to systems acquisition and management. The practitioners generally reported that decision makers did consult widely and well. Admittedly, the practitioners interviewed were successful users of CAD. We did not interview those who may had tried it and failed, or who were unable to cope to the extent that they went out of business.

We targeted specific issues in our questioning to see how firms coped with decision making. We asked about the difficulty of planning for the obsolescence of the equipment, maintenance costs, and costs of training and management, which are easily neglected in decision making. Only three of the practitioners admitted that acquisitions were made without taking all of these factors into consideration. According to one of these practitioners:

We are still suffering the consequences of leasing a computer system over 5 years. That was wrong. Five years is too long to predict, it doesn't leave you flexible enough. You have to pay as you go.

We then asked about "human factors" that might undergo change due to the purchase of computer systems. Does the firm plan its acquisitions taking into account human factors such as: changes in work practices; staff obsolescence; work conditions? A majority of practitioners gave positive responses. Some engineers and the consultants were sceptical that this was the case in their firms. One said:

I don't think that they [the directors of the firm] actively made allowances for anything that may or may not have happened. I think they just decided to get into information systems and see how it went, and they had a management structure that coped with various levels of day to day management and they just took it form there. I don't think that there was any planned obsolescence. There was a turnover in the practice that allowed you to cope with that obsolescence fairly readily.

How do practitioners decide to invest in computerisation, particularly CAD? We took it for grant in our study that practitioners do *not* invest in CAD to improve productivity, and that the rationale people offer for their decision making is more subtle. We asked the practitioners whether the main reason the firm started in CAD was that more clients seem to require CAD. The practitioners were split on this issue. Those who disagreed with the proposition appealed rather to productivity and efficiency. But the question succeeded in bringing out some of the ways that CAD is introduced into a firm other than through carefully deliberated policy.

The reason that any organisation gets into CAD is that there are staff that want it and they exert pressure on management. It's hardly ever taken objectively. … It's the guy smuggling in a pirate copy of [name deleted] and putting it on the word processor that starts a firm in CAD.

A lot of them are taking the approach that CAD is coming so we might as well jump on the bandwagon now.

Searching for responses that identify problems in decision making we asked if the most difficult thing about selecting equipment was its immanent obsolescence. We were thinking of the problem of buying the latest computer equipment only to find that it has been superseded by something much better. There was some disagreement about this proposition, but the majority said "no." Some practitioners indicated that the most important component of a computer system is the software, which does not become obsolete quickly.

Good software is always upgraded. You buy your software and the hardware will look after itself. On the surface hardware is your biggest cost. In reality it's not. Your biggest cost is first the cost of staff gaining skills and the associated cost of training people when the staff leave.

Equipment selection appears to be less of a problem now due to the decreasing cost of hardware, and the high quality and flexibility of computers. Some practitioners posited a solution to obsolescence which is to purchase at the top of the range, rather than buy the cheapest. The other solution is to simply plan expecting the current machines to be obsolete in a couple of years.

We also asked about the role of computer vendors in the decision making process. We asked if practitioners were at the mercy of fast talking computer vendors in making hardware and software choices. Most architects and consultants disagreed with this proposition on the basis that they recognise it is not good practice to rush into such decisions without in-house knowledge. It appears that the skill is to have sufficient knowledge to ask vendors the right questions. Amongst those who see the pressure from vendors to be a problem, one remarked:

Yes, you certainly are to some extent. We didn't know which hard drive tape backup unit etc was going to be the best. The tape backup drive that we originally got, no one will service so we've had to change over.

We then focussed on the notion that design practices have not traditionally been capital intensive. Having to think about capital resources is a major change. The majority of interviewees agreed that having to make decisions about capital resources was a major change in design practice. However, this view is moderated by the scale of the capital involved, particularly the scale of costs involved relative to the staffing costs associated with IT.

It's nowhere near as costly as the staff member using it. Industry has accepted that for years.

Stress in Decision Making

We asked if decision making in relation to IT imposes any stress on the firm. The majority said that decisions about IT are now becoming everyday decisions. The stress comes from the *initial* move into computer-supported work. Most confirmed that the modular and low cost nature of computer purchases obviates the risk. Among those who saw decision making as stressful, one practitioner indicated that practice is undergoing a transition from a craft to a production industry, and we are not prepared for it.

It imposes stress because you are going from a craft based industry to a building production line process. You have to do things in a logical order, a lot of architects and people managing design don't think logically, and they get caught out.

In the light of these comments pertaining to management we asked if the particular firm in which the practitioner was involved had coped well with the changes brought about by IT. A majority of interviewees said that their firms had coped well with what was until recently an alien technology-though there were

reservations. They reported some specific difficulties. Some difficulties pertained to false expectations about speed.

It's had its ups and downs. People think IT will be much faster, but putting the drawing on the computer initially takes as much time as on the drafting board. It saves time with changes and multilevels.

For one practitioner the introduction of the computer represented a change in culture to which architects do not easily adapt.

Average-mainly because architects do not think computers, they think art, which makes it difficult for them to maximise the benefits of using computers. Computers don't produce freehand wavy lines. They produce hard lines to exact dimensions. Architects by definition don't work that way. It's foreign to them.

According to one practitioner the effects of IT were negative.

It has had a negative productivity and financial impact. In terms of the staff, things have been fine, but in terms of getting the product out of it, we have not coped. We are not unique in this.

The worst scenario is where the computer is purchased but not used.

You see firms that buy a system and then have it sitting in the corner, whereas other firms buy the system and installation and training to get over that first hurdle and then they can pursue it themselves. In the early stages especially the training and support is essential.

We asked what common mistakes practitioner had made in the purchase of equipment. The majority did not admit to making serious mistakes. But the mistakes mentioned included being committed to elaborate and long term lease arrangements, underestimating the benefits of purchasing Macintosh PCs, purchasing equipment not supported in the country so that it had to be sent overseas to be repaired, wrong choice of back-up system, and giving insufficient priority to systems management. Some regretted being committed to the text interface DOS system in the light of the user-friendly Macintosh and Windows environments. Firms that got in early and had mini computers seemed to regret that they could not now shift readily to personal computer systems because they had already trained their staff on the old system. Many of these problems do not appear to be abiding. Some practitioners appear to have been caught out by the transition from large custom built systems to flexible, modular, powerful and user-friendly personal computers and workstations.

The next transition will involve laptop computers, computerised notebooks, advanced digital communications and multimedia, which appear generally to be compatible with the current style of personal computer and workstation, and there is a growing compatibility between operating systems. We expect that practitioners will report fewer regrets with hardware choices in the future.

The Cost of Computer Systems

We asked if the rapidly falling cost of computers had made the selection and management of computers less critical now than it was five years ago. Some reported that costs have not dropped.

Hardware costs have dropped but software hasn't. The cost of training has gone up. You don't go out and buy a PC any more. You buy a 32 bit workstation sitting on a very expensive network.

Others suggested that as the costs drop you buy more equipment, or more expensive equipment. It appears that software costs are still high. Also, due to the economic climate, firms are working with lower profit margins and there is less money available. These responses suggest is that it is the modularisation and flexibility of modern computer systems that makes the selection process less critical now rather than simply cost.

There are indirect problems with the reduced cost and hence reduced priority given to hardware. One practitioner reported that the reduced cost of hardware means that less money is spent on managing it.

Five years ago with the kind of investment you made you had to have someone experienced in the field to manage it. Now that the cost of the hardware and software has dropped so dramatically they're not prepared to spend a decent amount of money on getting someone in to manage it or set it up for them. They're buying the equipment without buying how to use it.

To explore further this balance between people and equipment we asked if the practitioners agreed that computers are now "cheaper than people," so firms do not need to maximise the use of equipment (by scheduling after hours use etc). Most practitioners agreed, and some were highly critical of attempts to ration out the technology.

They [computers] should be like telephones, they should be on everyone's desk.

If you can afford a staff member you can afford a machine.

Practitioners reported that in the past they organised work shifts to optimise the use of computers, but not any more.

At first we had 3 eight hour shifts. Now they [computers] are more like typewriters. Its not a problem if the computer is just being used a couple of hours a day.

But, according to one practitioner

the 90s are going to be the time of the capital intensive office rather than the labour intensive office.

One of the practitioners who disagreed that computers are "cheaper than people" remarked that computers are only cheaper if the capital cost of the equipment and all the associated tax benefits provide a greater productivity than the equivalent cost of hiring somebody, at least for drafting. The practitioners who reported as much appeared to be those with large minicomputers or those involved in leasing arrangements. Another practitioner remarked that as long as there is a heavy workload (the firm is doing well) then the staff costs are higher than the equipment. With less work there is less intensive use, and the equipment represents a larger relative cost.

Training

One of the major changes we hypothesised was the commitment to training that firms have to undertake. Training was conducted in-house, on the job and through formal courses. Some of the practitioners regarded formal training as a way of getting started with a particular computer package, but that was no substitute for in-house on the job training. Some reported that training occurred out of hours and was sustained by the motivation and enthusiasm of the individual. One practitioner said that their firm focussed upon user friendly systems that do not require extensive formal training. Only secretarial staff are sent on training courses. Again, those for whom training was a major issue were those firms with specialised turn-key systems. Some firms even had to send staff to the US for training. We expect a trend away form this requirement as systems become easier to use, and more students graduate from universities and colleges with the necessary skills. However, there was a consensus amongst the practitioners that training is an ongoing issue. The factors that contribute to this ongoing concern with training include the problem of keeping up to date with new releases of software. According to one practitioner training is becoming more important.

As the system expands your productivity drop is more important with each person who does not know what to do.

For some practitioners training in the use of the CAD system is less significant than being trained in the organisational side of the system-office practices pertaining to standardising title blocks, use of layering systems, font sizes, etc.

We asked if the firm takes training into account when purchasing hardware and software. Most practitioners responded "yes." Some of those that responded "no" thought that the software should be user friendly, so formal training should not be an issue. Some thought that training should only be necessary at the outset, as a one-off cost, and thus should not be the major determinant in the selection of a system.

We had hypothesised that one problem with training is the mobility it gives staff. You are generally training staff for their next employer. The majority of practitioners agreed with the proposition, but they were divided as to whether or not this was a problem. A number commented that their firms were building up a pool of expertise which they would be able to draw upon. Further comments were made that it was short sighted not to train people out of fear that you would lose them to the next employer. One senior practitioner thought that if you train people "they recognise that you have the right attitude." According to another practitioner trained people leaving is not a problem as there is a pool of expertise out there sufficient to meet the demand.

Today it tends to even out. As many people have now been trained, we pick up just as many as those who leave us.

We proposed that enthusiastic staff feel they can advance their careers by acquiring computer skills. Computing is therefore career enhancing for some. This enhances their mobility. Only two survey respondents disagreed with the proposition that computing is career enhancing. For those who agreed it is no longer so much a question of 'enhancing' a career as being a necessary requirement. Those who disagreed saw it as a "dead end" job for some people, thinking perhaps of those who become cast as CAD operators.

CAD Operators and Managers

We also put it to the practitioners that perhaps CAD has introduced a new dimension of tedium to design practice, and that the position of CAD operator is to be avoided by professional designers. A majority agreed with this proposition, but many qualified their agreement based on the observation that this situation is changing as more professionals are entering practice with CAD training, and are using CAD as just another decision-support tool.

I do not think the idea of using CAD is to have a draughtsman sitting in front of an electronic drawing board instead of drawing on a drawing board. There is a lot more scope in the system which architects and designers should use, but it is the old problem. Architects feel it is a stigma and they are afraid of it. I think with time we will overcome those barriers, but not in the near future.

A lot of professional designers are scared of becoming a CAD operator, but to be able to use the computer properly you need to become an operator first before you use it to design.

According to one practitioner it depends on the way that you run your practice as to how the CAD role is defined. For large projects the CAD operator may simply be implementing the decisions of others. If the same staff involved in the project and responsible for parts of it are those who also draw it up then the CAD role is not demeaning. Another practitioner went so far as to suggest that for those firms where the CAD operators is "somewhere down near the print boy" the office is inefficient. For some firms the role of CAD operator is shared.

We expect everybody to be a CAD operator. We are not distinguishing between architects and CAD operators, anybody who cannot use a CAD system is unusable in the way we run things.

People end up as 'operators' because the other designers will not take the time to learn to operate the machinery. You will get to a stage where unless you can operate these machines you won't get the jobs.

Even where some staff end up operating CAD systems the job need not be tedious.

You still get a situation where you get people who are specialists on CAD whether it be structural analysis or computer-aided drafting. I find that they don't feel that their job is a tedious one, they enjoy pushing the buttons.

The more glamorous side of the CAD business is CAD management. We asked the practitioners if this is a growing area of specialisation. CAD management seems to include managing the computer system, and also deciding how the CAD system will be used-layering conventions, customising the menus, organising files, etc. Most agreed that CAD management is a growing area of specialisation, but some suggested that in the future it will only be of relevance to the larger computer installations.

Systems management is clearly a problem area. Problems reported include the fact that "all the wrong sorts of people are getting into it," people who are good at it are hard to find, for some it is perceived as a dead end job, and CAD management is sometimes "out of sync" with the goals of the directors of the firm. Those who thought that CAD management is not a growing area of specialisation contended that with CAD the requisite skills will be absorbed more into the skills base of the average practitioner.

There are few good people about in CAD management. I think it might be declining as CAD skills are absorbed into the profession.

One practitioner contended that much of the CAD management role will be met by more sophisticated software. The role of the CAD manager will therefore diminish.

In the next 10-15 years the increase in the use of artificial intelligence will automate the management of systems in terms of making sure that you've got the right layer, with the right things on it, in the right place, in the right file, on the right job, at the right time. A lot of the tedious stuff will be dealt with automatically by increasingly sophisticated software.

This is already the case according to one practitioner.

You do not need very specialised skills to keep a system going.

Management and Organisation

We proposed that computing tends to heighten the need for personal and corporate organisation. We questioned the practitioners to test this hypotheses. First we tried to ascertain to what extent organisation was an issue for the practitioner concerned. We asked whether the practitioners regarded themselves as organised. Clearly organisational skills are an issue with those interviewed, though some expressed their desire to use work time more effectively. We then asked what impact computers have on personal organisation. Does the use of computers require one to be better organised than otherwise? A majority of practitioners said "yes," though one practitioner remarked that the profession of architecture requires a certain amount of organisation regardless of the technology. One practitioner drew attention to the ability of the computer to enhance organisation.

No, it doesn't require you to be organised but it keeps things organised for me. I use a Mac all the time now. When I feel like doing things, I flick through things I haven't thought about for a month and think more about it-your ideas don't just drift away.

For one practitioner computers allow you to be less organised.

The reverse is true we can keep things until the last minute.

We pursued the question of the computer as an aid to organisation by suggesting that computers are a

valuable aid to organisation. The majority of practitioners agreed with the statement, but several interviewees noted that there are occasions when the opposite is the case.

If they're not used properly they can create more problems within an organisation.

We have used the computer as a tool in program management and it has helped there, but in other areas it is probably more of an encumbrance.

Adopting a different tack we asked if computers *instil* good organisational habits. There was general disagreement with this proposition, usually because computers "don't make a good organiser out of a bad organiser."

In themselves they can lead to chaos.

There was also the suggestion by practitioners that organisational skills and computing go hand in hand as "people who are well organised take to computers-others don't."

Perhaps computers have a negative effect in that they force rigid organisational habits onto people. A majority of practitioners disagreed with this proposition. It seems that the individual worker has a fair degree of control of how they use the computer. According to one practitioner "it's like the filing cabinet; it depends on how you use it."

Even if at a day to day level the relationship between personal organisation habits and computers is not critical then perhaps organisational "catastrophes" are more prevalent or more severe with computers. We suggested to the practitioners that mistakes due to poor personal organisation can be catastrophic when you use a computer (due to file loss, etc). The majority supported this proposition pointing out that even minor mistakes can cause major problems. But according to one practitioner, as long as "your security system is right, you have backups etc. the chance of a disaster is quite minimal." According to one practitioner:

It's no different to losing a letter, or spilling a cup of coffee over a drawing negative.

We then turned our attention from the organisation by the individual to the management of the firm. We asked if computers assisted in the management of the firm, and if so in what way. It appears that computers were used by all the practitioners interviewed in the management of the firm. The main areas of application are in job planning, accounting, financial projections and administrative tasks. One practitioner noted that their firm had undergone "a tremendous reduction in administrative personnel" as a consequence of computerisation.

Management of Projects and Documents

We asked if computers assist in the management of projects, and if so, in what way. It seems that computers are widely used to assist in the management of projects. The main use is in keeping track of the project administration and in improving the response time for variations or to requests for project-specific information. One practitioner articulated the benefits at length. The benefits include keeping track of variations on a complex project.

One of the great attributes of our system is that we can write macros very easily. All of the housekeeping functions that traditionally kept draftspeople busy in an architectural practice-amendments, variations and the tracking of variations. We wrote macros to control all of that so that a person couldn't log off their drawing unless the variation was logged on properly. The creation of amendment columns and the automatic numbering of amendments across all documents effected by the amendment we wrote macros for. So we would change something once on the 1:100s and wherever that detail was affected it was logged on automatically. That meant that we were able to run a complex commercial project ... which changed its leasing environment three times during the period of construction. There were 260 client induced variations all

of which were tracked perfectly in our written database and on our drawings. The job captain, who was a director of the company, knew at all times that those amendments were up to date. The speed with which we could get those amendments back to site was very fast. That endeared us to the process of construction which meant that everything went smoother. We now believe that we could not have done that project without CAD. That's why the building bristles with commercial activity. All the life of the project was allowed to happen because it could be monitored, rather than frozen out because it was too hard.

All of this suggests that the management of a project that uses CAD is different to the management of a "conventional project." We put this to the practitioners, most of whom said that it was different. Some said there was no difference, but they generally considered the question in terms of overall management decisions rather than the process itself. It seems that CAD changes the way practitioners manage drawings, and as drawings are so central to the progress of a job the management of the project is affected.

There is a certain logic to the progression of drawings when done by hand which is different when done by a machine, and since the progress of the project is related to the progress of the drawings, you have a different sequence of drawings.

According to another practitioner it is necessary to structure the production of the documentation in "a more logical way" than on a manual project. There is a strict sequence imposed on the production process. You need the 1:100 drawings before the detailed overlays can be produced. With CAD there is a heavy interdependence between drawings.

If you're doing a project manually you do not have as heavy an inter-reliance as you do with a CAD project. For instance, you can start at any time on a new sheet, get something out of the drawing cabinet etc. In CAD you tend to take something that's already been done, enlarge it, put extra detail on it, etc. You are relying on something done previously so there's much more linkage, which means it has to be thought out and planned much more.

A further major change is that known and precise information can make its impact felt right at the outset of the project rather than later on as the project is refined.

Yes, completely different because fundamental information can be fed in so early. We start modelling our buildings immediately on CAD, that might be just by definition of an area, or a space, or a commercial premises of some kind. As it turns into an architectural process we keep on modelling it. So the reporting is early and accurate. I could show you schematic designs for projects that we've done in a week that are virtually working drawings. That's not hard to do.

Clearly CAD challenges the practice in which a design progresses from imprecise and ambiguous beginnings to a refined and precisely defined form.

There's a lot more thought required initially in a design. You have to make a decision as to what type of construction a wall element is made of a lot earlier.

This emphasis upon precision imposes new ways of working.

You have to organise the way the information is arranged on the CAD system differently to the way that you would on a normal hand done project. The information that you supply has to be clear and concise, in such a way that an operator can follow it easily.

The information has to be correct.

You can't just fudge information. If you get a survey from the surveyor and you put it in the computer and it's not quite correct, you have to get it right.

The payoff is that CAD introduces various efficiencies.

Rather than doing things manually over and over again we're doing it on a computer which gives us the facility to shortcut

things. If you were doing a schedule of furniture items manually you would do a schedule of each item. In a database you can put that information in once and extract it in many different ways.

These comments are at variance with those of one practitioner who noted that firms using CAD tend to mimic what they did in the past but at a faster pace.

Clearly CAD is a resource that has to be managed. We wanted to find out if the fact that access to the computers has to be managed and organised places an extra burden on the organisation of the practice. Few practitioners considered access to the computer to be a problem especially where computers were on everybody's desk. As long as computer are ubiquitous in the office then there is no problem.

You don't manage access to drawing boards. You put one on everybody's desk.

We then asked if perhaps the purchase of hardware and software, training, maintaining databases, software and manuals place a management burden on the practice. Most interviewees agreed with the proposition. However, several of those who agreed indicated that this may be because management does not take an active role in such decisions.

We asked if design practitioners are adequately equipped to cope with the management issues imposed by computers. There was an even balance between those in agreement and those who disagreed. Responses ranged from a concern that designers are "scared of computers" and shouldn't be exposed to management issues, through to a recognition that

designers are designers and then there's another breed of people called design managers. They're the people who have to help produce the project. When you look at other industries-advertising agents, movie producers-they have creative directors and they also have producers and account directors. They manage the client and the process and to a certain extent the designers. If you're a good designer you have your mind on one thing. You don't necessarily want to go off and manage the process.

Then there is the extreme view that computers simply don't raise management issues.

I think they liberate designers from all of that.

Bottlenecks and Systems Failures

We then tried to detect indirect evidence of management problems. A common symptom of management problems appears to be poor provision for contingencies. We asked the practitioners: What is the weakest link in your computer system? What would happen if there was a systems failure in this area? There was a range of responses. The most common concern was with output facilities such as printing and plotting. Other technical problems mentioned included file transfer and software integration, remote access to a mainframe and networking, integration between the technical (office administration) and CAD systems, the power supply and software failure. Only one practitioner mentioned backups as a problem. Some responses highlighted the user interface problems of certain operating systems as a major bottleneck, and others reported the difficulty of raising adequate finance. Several practitioners reported problems between the people involved-the weak link being the potential for breakdown between designers and CAD operators, and between the systems people and general management.

For more specific responses we asked what contingencies did the practitioners allow for system breakdown, catastrophic file loss etc. The majority of practitioners reported that they rely on a back-up regime in the event of breakdown. The frequency of back-up mentioned (and therefore the severity of file loss in the event of failure) varied from monthly, to daily and even twice daily. Other forms of contingency included taking out an insurance policy against data loss, and running a parallel system or network of discrete systems between which each job might be swapped. One practitioner spoke of the backups as "windows" into the progress of the job.

I tend to believe that you rebuild your whole business so that you have windows of your business. If someone wanted to look at something you'd ask them when it was, say, May '89. You'd get the printout of the directory of everything that was in the system at May '89 (20 pages or so). They'd flick through that and find the file that they wanted. What it gives you on major jobs is windows of the progress of the jobs-important in legal disputes etc.

One practitioner also relied upon a network of other practitioners to assist when equipment goes down.

We have a network of other offices we know, so in case of a breakdown we can borrow or hire equipment. Our back-up system and our network friends are our recovery program.

Systems Managers

The role of systems manager had already been raised by most practitioners. We asked if the firms employed a systems manager, and if so what was their role. Half of the practitioners employed a systems manager. Amongst those who did not, some had a person on staff who was both a design architect or engineer and a systems person.

In smaller firms it tends to get added on to somebody's job.

One large firm employed several systems managers.

Yes, there are several people in that role. One looking after the hardware (backups, making tapes, physical hardware); one looking after software on the CAD side; one looking after software on the Mac side and keeping inventory of software releases, licence numbers etc.; and a senior CAD operator appointed on a project by project basis.

In another firm

The systems manager innovates the writing of macros. The CAD manager organises the resources and the training and the running of the system and is our most proficient operator.

For some the systems manager role is also that of CAD manager. One firm defined the role of the CAD manager as a production manager, analogous to the production manager in manufacturing.

A CAD manager is really a production manager. Because design firms have been craft oriented in the past they've managed to get by without production managers. They're responsible for the machinery and the effective flow of work through the business.

To test the importance of this role we asked what would be the immediate effect on the firm and its use of computers if the systems manager suddenly left. The responses ranged from "catastrophic" to "no problem at all." Those practitioners for whom it would be no problem said this was because the relevant expertise was distributed throughout the firm, or at least between more than one person. For some the loss of the systems manager would be only a slight problem as there were others in the firm who could take over, if they had some specialist re-training. In other cases firms would need to employ a new person. But this was not seen as a major problem as there are plenty of people with the necessary skills on the employment market. We asked specifically if expertise in systems management was distributed throughout the firm. In the majority of cases it was not.

Systems Manager Training

We asked if there is a need for specialised training for systems management. The majority of practitioners said that there is a need for specialised training. Some said that it should come on top of a professional education. We asked which form of training would be useful for systems management. The responses were

(in order of most to least importance) for professional development courses, university postgraduate degrees, and part of an undergraduate education.

It's a strand of management. You have to have management training. Management as a whole and practice as a whole in universities is weak.

Clearly, there was also a preference for the systems manager to also be trained in the design discipline-architecture or engineering.

All architects and students should receive training in this area at all levels as distinct from having specialised training programs for professional system managers.

It has to be somebody with a background in design, a designer or an architect.

Some practitioners also hinted that the role of systems manager is one that is diminishing in importance. We asked if the role of the systems manager will increase or decrease in importance in the future. There was an even balance of responses. The general reason given for increased importance was the growing number of users and volume of information to be supported by the technology. On the other hand the importance was seen to decrease as systems become easier to use and more users become familiar with the technology. Practitioners in large firms or who use large systems saw the role as an increasing one.

The introduction of networking with its devolved computing power, as opposed to stand alone or star systems, has assumed that system management responsibility would be devolved also and I just don't believe that's true. Moving from a 17 station star system to a fully networked system has increased the management requirements ten fold. I don't see that changing but I'm hoping that, for example, you won't have to know Unix, or if you do that you will have learnt it at school as a ten year old.

Amongst those who see the role of systems manager declining:

I think the large firms will probably always need somebody-at the moment they're telling us it needs to be one for every six people-I think it will probably be less than that as people become more familiar with it.

Systems Managers and the Firm

We also inquired into how well the systems manager is integrated into the firm. We asked: how would you describe the relationship between systems management personnel and the rest of the firm? We asked the practitioners to respond to a number of possibilities: (no problems; amicable relationship; systems personnel appear protective of their expertise; or other staff are not very understanding of the pressure a systems manager is under.) None of the practitioners disagreed with the first option-that there are no problems. None disagreed with the second proposition-there is an amicable relationship. It appears that some systems personnel are protective of their expertise, but most practitioners did not see it as an issue. The majority agreed that other staff are not very understanding of the pressure a systems manager is under, though at least a third of the practitioners did not see this as an issue. (Perhaps they did not understand the pressure a systems manager is under.) One practitioner who saw problems said that

the systems manager must be trained as an architect and have a professional rapport with the rest of the staff.

For one practitioner the situation is different now to several years ago.

The systems manager used to be in an "ivory tower" but now tends to come from the ranks so it's a different relation to that in the past.

There appear to be different problems in large as opposed to small firms.

In small firms because they are part of the team there are generally no problems. In the larger firms it tends to be a separate person or a separate division. In those cases you can get isolation, people being protective.

For another practitioners problems with systems management in large firms can be attributed to poor management at the director level.

That [systems personnel appear protective] depends on the attitude of the directors of the company. If management throw up barriers and you have an organisation that doesn't give out information, you'll find the system manager is protective of his expertise. The systems people wanted to give out the information but the other people didn't want to know. They didn't perceive it as being part of their job.

One of the interviewees had the role of systems manager, and complained that people did not understand his role, but that did not impede his work.

I don't think other staff know what I do, but management know that I provide all the support that they need as far as them taking their decisions. I think the user staff (the technical staff) accept the technical support I either give or arrange for them to have.

Physical Work Environment

We hypothesised that spaces occupied by computers have a distinctive character which is sometimes at odds with the environments in which designers prefer to work. We wanted to find out how computers are located in the firm, whether or not computer workstations can be personalised, whether they support the culture of the designer, whether the narrow range of physical activities they support is a hindrance to design, whether or not computers are seen as cold and unfriendly, whether computers enhance communication or hinder it, and whether computers extend the work environment by allowing people to work from outside the office.

Locating the Equipment

We first asked the practitioners how they decide where to locate computer equipment. It appears that the decision is based either on the work practices of the firm, or on technical considerations. Those who answered from the point of view of work practices mentioned that their computer equipment is either located centrally, relative to each project, according to space availability, or on each desk. The technical considerations included lighting and glare, radiation, air conditioning and ready access to printers.

There is clearly a trend away from locating computer equipment centrally. One practitioner summed up the trend as follows.

We used to have all the terminals together. There are some pluses and minuses associated with that arrangement. For the last year we've had them in a distributed environment and there are some nice things to be gained from that.

According to another practitioner computers are located

where the people would be working as a matter of course. I have a personal preference for grouping work stations relatively close to each other so that if people have problems they can talk to each other, but by and large they're spread everywhere. With the latest technology there's no problem with lighting. You don't put them in front of a window, but with this sort of environment there's no problem at all.

Glare from natural light was a major issue for some.

It was a real problem because we designed this place to have excellent natural daylight for conventional drawing. That can be a real pain for a CAD screen because you get reflections everywhere.

Clearly flexibility in the arrangement of equipment is important. According to one practitioner the equipment

moves around according to the project needs. Sometimes we've had a workstation in a team of people working on drawing boards, at other times we've had all the workstations together working on a project.

We also asked if firms had drawing boards and computers at the same workstation. There was an even balance between those practitioners with both a computer and a drawing board and those without. Drawing boards seemed to fulfil two functions when located with computers: as layout tables, and for emergencies. But for some practitioners having both is an unnecessary expense. In one of the firms the architects had both drawing boards and computers, whereas the CAD operators only had computers. For some practitioners having both was not cost effective.

That is not cost effective. You either have a computer sitting there doing nothing or a drawing board doing nothing.

In order to discover to what extent practitioners using computers are able to personalise their work space we asked if computer workstations are generally shared or personal. The responses were evenly divided, but there is certainly a trend towards dedicated computers. Of course, secretaries, administrative staff and directors commonly had their own dedicated machines.

At the moment they're shared but we are trying to make it one per desk. However, anyone should be able to use anyone else's terminal (like a telephone) so in that sense they should continue to be shared.

The intention is that they're shared because we can't afford to give everybody a workstation. In practice what will happen is that if you use a terminal for four hours a day you'll get one on your desk. If you use it for less you'll go to a shared workstation. The workstations aren't just used for CAD. There are hundreds of programs running on them.

Computers for Design

We asked if computers are used for sketch design and design development or mainly drafting and modelling. The architects we interviewed revealed a broad range of uses including both sketch design and design development, drafting and modelling only, and design development, with one practitioner using the computer for sketching only. The engineers, on the other hand, were mainly interested in drafting and modelling. For one practitioner the use of the computer has reduced the amount of time spent with "butter paper" sketches.

We start on butter paper but quickly transfer in order to save time

Computers have clearly revealed and enhanced an important aspect of the design process-the fact that much sketch designing involves the modification of previous designs.

They are certainly used for sketch design and design development where editing is used. A lot of projects are modifications of previous projects. So if you're doing a multi storey building at the early stages and you want to do it quickly, you can often bring in a core or some form of a previous building, so you can build up a drawing very quickly from components.

It seems that the use of computers has also blurred the distinction between sketch design and drafting.

Drafting and modelling are part of sketch design development. Every job that we have has some computer development. We've done some jobs from sketch design and others from a later stage.

Where firms were using large, elaborate CAD systems that seemed to be an impediment to using the computer in sketch design, even though the system has sophisticated capabilities.

Regrettably, [the major application is] drafting and modelling. That's not the intention. The last people who convert to it

are designers. They're lateral rather than logical thinkers, but our designers are now becoming skilled at CAD and they're inclined to sit down at a terminal and knock it out. The [name deleted] system is rather easy to use in 3D, but we've got a long way to go. You make the money in knocking out the documents so it's there that it is most cost effective.

For one practitioner the computer has introduced a new way of doing sketch design.

Concept designs tend to be on butter paper but they are transferred very quickly to CAD, some manipulation is done, then you spit it out again on the laser so that you're actually dealing in real dimensions, and then you work on butter paper again.

Computers Versus Drawing Boards

We then put it to the practitioners that perhaps computer workstations (for design and drafting) support a narrower range of physical activities than the traditional drawing board arrangement. People do not move about as much, they appear transfixed at the computer screen, they do not welcome intrusions into their work space, and they may even appear less sociable. We asked if the practitioners agreed with these propositions, and we asked for their observations of the way people work at computers as opposed to drawing boards. The responses were marginally in favour of our proposition. For one practitioner design is a solitary experience anyway.

The people who appear to be more sociable are the people who are detailing. Designers are actually more inclined to want to get away on their own and think.

I think they work in a similar sort of fashion. Some of them can be intense, some of them can be fairly easy going. It depends on the person. There is a certain amount of introspection with the terminal because you're sitting in one place and looking at it all the time, but I suppose the same thing can be said about a drafting board.

Considering computers as opposed to drafting boards: you do tend to get locked into place. Manual drafting is probably much better for exercise. You need to design the workstations around the individual rather than have the individual move from item to item.

According to some practitioners working at a computer is more intense that working at a drawing board.

Yes, computers are more intense because you are dealing with something that is very powerful. You can lock into it as an intellectual task. On the drawing board a lot of things can get quite dull, but I think people lock in on drawing boards when they're designing. There's also another pressure in that people on the computers are trying to prove how good the machine is and how much better they can do the job. So they tend to work harder. In years to come when everybody has a computer screen this will change.

Yes, computers requires more concentration. You don't like being interrupted as much. You're far more productive if you're not interrupted. Computers seem to gobble up time much more than the drawing board ever did.

CAD also requires you to think about other things than when at a drawing board.

I think you need more attention because you're not just drawing a line, you're thinking about how long this line has to be, and you're thinking about the X and Y coordinates.

One practitioner did not see any substantial difference between working at a drawing board and working at a computer in terms of interaction.

They [the computer operators] are very interactive with the people around them. They do get up and walk around. A computer is really the same thing as a drawing board.

One practitioner interpreted the relative inaction of computer operators as being more relaxed.

I think with computers people are more relaxed. If they need to get close to a particular aspect of the drawing they can just zoom in instead of having to physically lean over or squint.

For one practitioner there are other factors that contribute to the degree of interaction between people in an office.

The difference in the way people work is more to do with the physical arrangement and layout (lighting, etc.) than anything else.

Some practitioners proposed solutions to the problem of the apparent self absorption of the computer operator.

They [computer operators] should be interacting with the decision making of the project so that shouldn't be happening. There should be dialogue between the decision makers, be they technical decisions or design decisions, happening through their day that keep everyone in the office communicating.

One solution to the apparent stress of working at a computer is to take frequent breaks.

You do feel physically cramped when you're working at the screen, I think you need to take a break very regularly. I guess we do so many different tasks that it's generally not a problem with us, although on occasions when I have to get out a drawing you know it by the end of the day.

One practitioner had experimented with a better ergonomic design for a computer workstation.

One thing that I implemented with our GDS systems was to have on one side or the other of the workstation an adjustable sloping reference desk, you could put the drawing that you were referring to on the sloping surface so that you only had to turn your head and it was there, but they were quite expensive and we couldn't afford to fit out the office like that.

We also suggested to the practitioners that environments populated by computers may be cold and hard compared with the more casual human environments centred around drawing boards. We asked if they agreed and, if so, if anything is being done about this in the firm. Most thought that computer environments are not inherently cold and hard. The image of computer environments as being cold and hard is more to do with office layout. Some of those who agreed with our proposition said that it is due to insufficient attention being paid to the design of the workspace.

It's because nobody pays any attention to creating spaces that are user friendly for the people and the equipment.

One firm even kept drawing boards to keep the work environment friendly.

That's the reason that we haven't gotten rid of the boards. You come to work for fun as well as work.

According to one practitioner computers are caught up in a game of image making by the firm, and it need not be so.

It's an image thing. A lot of firms want to push that high tech stainless steel and brick image, and computers can be part of that. Some of the big firms invite the clients around to see that all the technology is there and that tells them something.

One firm attempted to overcome the problem of the sterility of computers by better spatial integration, though there are problems.

We attempt to integrate the work stations into the general office space, rather than have a separate section. The big problem there is the very different lighting levels required by each. The problem is almost insoluble because you don't want bright lights near a computer screen.

Computers and Communications

We suggested to the practitioners that CAD and IT provide unprecedented opportunities for collaborative design activity: collaborative design at a distance; communication within the office through electronic message and memo systems; shared work areas on the computer screen; electronic communications with consultants; all electronic fax processing; electronic mail; electronic conferencing; and multimedia. We asked the practitioners if they agreed with these propositions. The majority agreed. But most of those who agreed also added that the potential is largely unrealised in design practice at present. The major beneficiaries appear to be large organisations who have consultants in-house.

There is no doubt that faxes make it much easier to get hard copy from one place to another but the use of electronic mail in most architectural offices is non-existent. To make it work properly you would have to have a large organisation with a high percentage of workstations to employees or it's self defeating. The exchange of information between various disciplines (eg. the architect and the engineer) is almost a non-event because nobody has the same system, even if they have the same system they don't have the same hardware or the same disc or tape drive.

Some practitioners appeared unaware of what was possible, thinking that comprehensive electronic communications were expensive and still some way off in the future. We expect that these comments would be revised in the light of the publicity given more recently to the feasibility of teleworking, the use of Internet, and the "information superhighway."

We asked specifically if practitioners thought that electronic communications were adequately exploited in the firm at present. The majority thought not. Only one firm reported using software that enables designers in different locations to work on the same drawing in real time-synchronous computer-supported collaborative work.

We're using Timbuktu [collaborative software for the Macintosh] to work with an office in Newcastle.

Only a few of the practices reported using electronic mail.

Some of us use electronic mail but it's limited to those people who have a screen on their desk.

For one practitioner security was a problem with electronic communication, though they had overcome this.

We don't use outside consultants so we don't have to worry so much about security, although obviously you have directory protection. There's no way a mechanical engineer or draftsman can alter an architect's drawing.

One practitioner took communications to include the whole matter of presentation. In this they included multimedia presentation as part of the communication process.

You have to communicate in the realm of concepts and ideas competently, and the architects hang around waiting for someone to pay them to do a colour perspective or a ray traced model of their design before the client ever really gets to see anything of what it's about. Architectural drawings are the limit of their domain. The truth is that there's so much media around that you can muster to give full expression to your ideas and these decision makers are subjected to communication like that all the time now, everybody gets presentations on videotape. If you're not competent in those communications fields you're going to be stuck in a sort of paper technological field.

But it appears that there is a trend towards greater use of electronic communications and the integration of this with CAD.

We aren't set up so that we can share all our files across the network. We're still doing a bit of disc swapping. That's a matter of time.

We asked if computers were helping or hindering the communication process. Computers are generally seen to be helping with external communications, data exchange, etc. (with reservations), but are not necessarily helping with the interpersonal communications believed to be important in design. According to one practitioner computers are revolutionising communications.

Helping! They've revolutionised it!

For some computing tends to be alienating.

It is hindering [communication] in the sense that the nature of the computer screen and the person transfixed there is very isolating and little communication is chosen to be undertaken by the person or by others-an alienating thing in some senses.

It has increased efficiency, yet centralisation and the specialised nature of using computers cuts down on communication.

Email is helping with communications externally but tends to reduce the level of informal face to face communication within the office.

On the other hand one practitioner did not think the computer is making any difference to communications, in the sense that we do not necessarily exchange more information.

I don't think they're making the slightest difference. You can exchange more information when you want to exchange it, but whether it's affecting the frequency of the exchange of information I don't know.

Teleworking

We asked if members of the firm are involved in teleworking-whether they have data links between home and work, and whether they are able to do some work at home because of this. Only a very few of the practitioners made use of such a facility-6 out of the 29 interviewed. Some reported that it is possible but not exploited as it should be. According to two practitioners:

Almost everyone has a modem.

Yes, our CAD manager has a modem connection to a PC at home. Yes, also I just transport my Macintosh.

Clearly there is a trend towards the practice of working from home, though there are impediments.

In a government organisation it takes a lot of change in policy. I can see a lot of opportunities for people to work at home.

Some work at home but are not linked to work via modem. Some use fax.

People do work on their PCs at home and bring it in on disc. Very few people access our network via modems.

Not modem link. A couple of people have faxes. Architecture is a face to face industry.

We asked the practitioners what they thought of the common projection that it will be necessary to come to work only occasionally. We also asked if it would apply to all levels of staff in the firm. It appears that this is already happening for a very small minority of architects, and a majority of others see it as a positive possibility. But some of the practitioners were highly sceptical of the feasibility of such a proposal.

That happens for some people now. I know at one architectural office they have almost as many people working at home as they do in the office. They're in and out. Some people want to be at work all the time with other people. It gives choice. It should apply to all levels of staff. I don't see why not.

It appears though that there are some technical problems to be overcome at the moment.

It's workable if one can get the whole of the information system working properly. It's not easy or fast enough to send a drawing through a modem at the moment. You'd have to come into work maybe three hours a day.

Some strongly disagreed with the feasibility of teleworking.

A lot of nonsense. Business doesn't work like that. Sometimes people go home just so they're not interrupted, but to say that you can run a major job by yourself from home is a lot of nonsense.

The main reservation was that you need the face to face contact with people-for the benefit of the client.

You still need that personal contact, and your clients and consultants want to see you in the office. If a person was only doing word processing or data processing they could probably work from home.

Some practitioners thought that face to face contact is also essential for supervision, management and the learning process.

It is possible, yet I question the perceptual and social aspects of that. It is a question of management confidence. It would not apply to junior staff because it is a management issue of monitoring function, etc. Also the education side of working in a firm is important. Control is the issue. It depends on how the practice runs. It would need specific guidelines.

It is almost impossible to supervise anybody at a distance, it's even more difficult if you're the owner of a company to be able to trust every single one of the people that you've got working for you.

But perhaps there are changes.

It's essential that you come to work occasionally. Face to face communication is so important. Maybe it's not so important for young people.

Teleworking is more feasible for individuals whose work tasks are well defined and relatively independent of other staff.

You could easily have say, a renderer who has his equipment at home. You could just send him the model and he would never have to come near the office. I can see it happening for some people (some consultants) but I don't see it happening as quickly as the media would have us believe.

This is certainly the case with design firms that specialise in software development.

A lot of people in our industry (software development) do tend to do that sort of thing. Coming to work's a habit. I know one person who lives in Adelaide but works for a Sydney company. He communicates by modem and comes to Sydney occasionally.

Bearing in mind these developments, we put it to the practitioners that the introduction of networked personal computers may be one of the most significant developments of IT in the workplace. There was general agreement with this proposition. We also suggested that this was in part because PCs enhance the autonomy and sense of self worth of the individual user. Only a minority agreed with this second proposition. Those who supported the second proposition provided the following evidence.

One feels more relevant with an expensive piece of equipment than with a drawing board, but not in the future when computers become commonplace.

The sense of self worth is because information equals power, until such time that enough people have that information or access to it. Then the power ceases.

If you are able to achieve more in a day it does enhance your sense of self worth.

Trends and Research Issues

There are clearly many developments in computer technology in train at the moment. We put several trends pertaining to CAD to the practitioners and asked how they rated their importance: increasing photorealism, better animation, virtual reality, improved information exchange standards, expert systems, tools for remote collaborative design, hypermedia and multimedia, and presentation techniques that simulate manual drawing. By far the most important of the trends we put to practitioners was the development of improved information exchange standards**.** According to one practitioner:

There's currently no way of transferring 3D. We've just had a job where it would have been very nice to get the engineer's 3D.

One practitioner was sceptical about our ability to realise improvements in this area, stating that

the moment that you try to create standards is the moment that people try to change them, but there would be a lot to gain.

The second category of trends that the practitioners favoured as important included increased photorealism for presentations. According to one practitioner so much of design practice comes down to presentation.

Presentation is half the sale.

Most practitioners were equally supportive of the trend towards improved animation techniques.

Expert systems were also seen as important. These are computer systems that simulate some aspect of professional expertise, and do so in a way that is amenable to updating and change-to the "knowledge base." These systems exploit computer programming techniques developed in artificial intelligence, and frequently make use of codified rules rather than programmed procedures. According to one practitioner expert systems are applicable because design practice is information intensive.

Information exchange means by default that you have access to a lot of information. Manipulating it is a province of expert systems.

Expert systems haven't taken off anywhere near where people thought they would, but that's partly because you need an environment rich in data.

However, there was some scepticism about what could be achieved with expert systems.

An architect makes a snap decision that would require an expert system to sort through hundreds of variables, and the data base has to be up to date. An architect might not make the correct decision but he makes it instantaneously taking all sorts of abstract concepts into account.

For some practitioners there is a lot of unrealised potential in the idea of expert systems.

I think a lot of the stuff which has been done is nonsense, but we'll get there eventually.

Potentially important, but I haven't seen anyone particularly take advantage of it.

The trend towards tools for remote collaborative design was also regarded as important, though there was little elaboration by the practitioners-perhaps as few practitioners knew of the developments in this area. Hypermedia and multimedia also rated as important, again, without elaboration. It was apparent that at the

time of the survey little was known about these applications, though they sounded interesting to the practitioners when they were explained to them.

Virtual reality rated slightly less in importance. A number commented that it was a long way down the track and that there was a lot of media hype about the phenomenon.

Datagloves-I think that sort of input device is the way that we should be going for design work. One of my basic problems is with the sort of input devices that we have, and I think that something like a 3D mouse, something that allows the architect to gesture, as if modelling with his hand, is incredibly exciting.

We also mentioned the trend towards miniaturisation (laptops, palmtops etc.) Slightly fewer practitioners saw this as an important trend, though there was still a majority of practitioners who saw it as important.

Taking the machine with you is important

The smaller the better. I don't go anywhere without the laptop now

I can't see them getting much smaller than a keyboard allows them to get. Then you've got a screen. I want to see the thing. Reduction in weight is handy. It would be good if the screen could fold up.

We also suggested the trend towards presentation techniques that simulate manual drawing. The majority of practitioners considered this an area of *little* interest. According to one practitioner "we have that already."

It's interesting what it does for client's perceptions of drawings. I laughed at it to begin with. I thought it was a real con. The same with hand lettering. But there's a point to it. Clients are much more inclined to have some input into drawings that look rough, and interestingly enough the lettering style that looks like hand lettering stands out from a machine drawing.

Experimentation and In-House Development

We also put it to the practitioners that there are now computer tools that enable experimentation with new ways of working and designing. We asked if this experimentation actually takes place in practice, and if so, in what way. Opinion was evenly divided. In several cases the experimentation was seen to be taking place, but as being ineffective, or as taking place in only a small number of practices.

I think the whole advent of CAD and PCs is itself such a tool, and that has changed the way that we work. About five percent of people in practice are [experimenting], they are constantly assessing new products.

Some of the examples provided by practitioners included the use of spreadsheets.

You can turn Excel [a spreadsheet program] into a design tool. Instantly you have a tool for exploring options with plot ratios.

Another practitioner was involved in the development of a custom built database system.

I am trying to establish a database system which will read off our drawing information which is relevant to my superiors in terms of occupancy, floor ratios, costs, etc. I would have to write an intermediate package due to the incompatibility of the drawing program and the database.

According to one practitioner there is no time for experimentation.

People don't have time to experiment in practice.

For others, the tools were considered too cumbersome.

There are very few tools that allow easy experimentation. For simple things like area calculations you can.

For one practitioner the computer encouraged experimentation with new methods of working.

Tackling a design brief by computer is different to traditional methods. Traditionally you had to follow a step by step process. Now you can do the steps out of sequence. You can jump straight five steps ahead and do a preliminary pass. It doesn't waste your time and it has a bearing on step 2.

We asked if practitioners saw any in-house development of customised computer tools. The majority of practitioners said that they did see in-house development. Much of this seems to be in the area of programming spreadsheets, setting up menus, libraries and macros. Reasons given for customisation included the specialised requirements of each office and the fact that vendors don't understand the needs of the designer. The comment was made that customisation may be intensive when a system is first introduced but that you reach a plateau where customisation becomes minimal. Some of the practitioners drew attention to some of the pitfalls of customisation: the expense, the expertise required, and the fact that idiosyncratic programs may be developed that people don't know how to use. For some, customisation is an important activity in their practice.

We're doing it all the time. We probably have about a thousand macros: from things that automatically generate drawing files and put them together to form the final plot drawing, to programs that will actually trace a line on the screen and put down spot heights at predetermined intervals in order to produce good quality 3D images (from contour plans).

There are traps to be avoided in customisation. The main problem is that in general the only person who knows how to use the customised tool is the person who developed the customisation. That can pose serious problems when that person leaves the firm.

You can't expect that your drafting system will do everything you want it to do so there has to be development. It's got to be carefully used because everyone can be going off and developing these programs and no one else can use them.

Customisation is also a particular skill.

We don't do a lot though because most of the people here are professionals, and they just want to use it as a tool, you've got to be a bit of an enthusiast to start writing macros.

It is not something practitioners particularly want to do. Customisation is undertaken to overcome the shortfall in what is provided by vendors.

Some, but mainly because the software industry is ignorant of the needs of architectural practice.

Some think that customisation is becoming less necessary as vendors become more in touch with the market.

Generally the third party vendors are providing better interface services.

Some practitioners disagree with spending a lot of effort on customisation.

I see serious in-house customisation as a waste of time. That is where you lose the expertise when people move out. I'm a firm believer that you buy proprietary tools. There are thousands of hours of R and D in those packages that you can buy for $5,000. I'm a firm believer in waiting for the proprietary product.

It generally ties you to that one individual or the one firm. You don't have the flexibility of working with general software packages and finding the best one to use and the best way to use it.

Understanding Design

How are these trends affecting our conception of design? We asked if the practitioners thought that the use of computers leads to an emphasis on form and appearance (due to computer graphics, modelling and rendering), and was it a good thing or not. The majority of practitioners said that they did *not* think that the computer led to an emphasis on form and appearance. Those that thought that it did saw this as a positive thing-making public ideas about the way that a proposal would look, ideas that would formerly have been the private domain of the designer. The majority of engineers believed that computers did lead to an emphasis on form and appearance, adding that they thought this to be a good thing. One practitioner remarked that nothing had really changed in this regard due to computers.

This hasn't really changed, you've always had perspective artists.

For some the emphasis upon form is a good thing and has meant that the client can see what the building looks like.

It helps the client to see what the building would look like at an earlier stage, but the client doesn't get dazzled by it.

computers enhance our understanding of design? We asked if practitioners thought that the computer helps our understanding of the *mind* of the designer. The majority of the practitioners thought not. Some practitioners reported that there was a conflict between designing and computer use. For some, the computer appears to have revealed the "illogicality" of the designer.

It's certainly formalised a lot of things. It's made you realise that designers aren't logical, that they can make two and two add up to anything that you like. So you have a conflict.

We also asked if the practitioners thought that it is now (or will be) possible to put design expertise into a computer. The majority of the practitioners said "yes." But most qualified their response by limiting such "expertise" to "technical trivia," such as door numbering and code checking.

Good offices that are well organised have an office procedures manual. Why can't you embed that, and you get the office procedure?

We could probably come halfway, but I do not think we can replace a designer with a computer. They will eventually be very helpful in the decision-making process. Computers are good at number crunching and storing information, and the extent of its use will be as a code checker.

Not in the sense of the qualitative human experience and feeling side of the design process, and the art side of architecture. The quantitative knowledge side of things, yes.

We asked what is the role of the computer in design, now and projected. Views varied from more extensive use of the computer throughout the design process (simulation, briefing, data bases) to providing an entirely new medium for design. Some practitioners were careful to point out that the computer would never automate the conceptual phases of design. Some thought computers would have a coordinating function, others that computers would allow designers to do certain things more easily (such as enhanced visualisation-multiple views and the projection of certain types of shapes). The responses acknowledged that creative uses are being made of the technology now. Most recognised that appropriate interfaces to make computers more amenable to design are on the way.

It's expanding substantially. Now we have the body of expertise to do it. Hardware, databases, simulation, optimisation was done in separate little programs in universities. Now that can be brought into the office environment.

Computers are great for solving problems a little bit at a time.

CAD allows you to better visualise and test your designs in three dimensions.

Some shapes are really difficult to draw on the drawing board so you don't even think of doing it , whereas on the computer it's not that difficult.

It gives an opportunity to take a look at design ideas and to see that in juxtaposition those design ideas work. Often somebody comes up with a concept and the size that he or she initially thought would work won't work. Complex geometric shapes don't necessarily work when they all come together. It's a visualisation tool of the reality that has been in the mind.

A means of documenting the design and exploring options. When I say documenting the design I mean full documentation, not just drawings. Briefing information, data used over the life of the building. The information used in design will have a longer life over the life of the artefact.

Predictions

We asked what the practitioners recalled were the major predictions about computing in design practice made ten years ago. It is clear that different practitioners were listening to different predictions: predictions of replacement (paperless office, no drawing boards, reduced staff numbers, word processing), design impact (3D modelling, system building, expert systems), and work practices (24 hour shifts, automated drafting, automated design). Most common were predictions relating to changes in work practices. A number of practitioners added that few of the predictions have been achieved in all areas, though most are there in some form or another. What were the major predictions ten years ago?

The greatest myth was the paperless office.

That a computer would do everything. That you would push the button at one end and it will produce a building at the other. A computer can't do everything. It's limited by the person who is operating it.

The people projecting the future always make it sound a lot closer than it is. Individuals have reached the predictions but not across the board. It's an ideal. Most people have to compromise.

There were predictions that offices were to run 24 hour shifts in order to make use of the capital equipment that they needed to have. There were predictions that there would be a lot of expert systems used to check designs and compliance with codes and so forth. I have not seen either of those happen.

Computers would make all buildings look similar. It would standardise, simplify and get things done quicker. A systems building process.

The documentation side is the only thing which has come true. The tools around for documentation now are excellent. As far as the design side goes they're still making the same promises and predictions as they did ten years ago.

We also asked what were the major predictions regarding computers in design. Again there was a great diversity of predictions; mostly that something new would become available (there would be expert systems, virtual reality, automated design systems), but also that the potential impact had been underestimated (that computers would have little impact on design). In all cases across the range of predictions, the practitioners thought that the major predictions had failed to eventuate. On the other hand, some practitioners thought that the predictions made ten years ago were not ambitious enough.

I think every prediction will one day come about. You tend to underestimate the predictions.

People didn't believe that it would make much of an impact at all. They wouldn't have believed that computers would have gone this far.

Ten years ago, nobody thought of computers as a design tool but just as a mechanical aid to production. I do not think anybody saw it as anything that a designer would ever touch. That anticipation of ten years ago has been proved incorrect.

There are clearly some predictions that have not come about.

Computers for showing the way that things would look, hinting at virtual reality, and we're not there yet.

That the designer would be designing and documenting straight onto it. That doesn't happen.

According to one practitioner there is one prediction that has fortunately not come to pass.

That they would stultify and inhibit design, but I do not think they have.

We asked specifically which of these predictions appeared to have been born out in practice. One practitioner said very few.

No very few, 1990 was the water shed between drawings and info data bases. Expert systems have yet to be taken up. There have been predictions about simulation and optimisation which haven't come about because the building model (which has to be the glue) doesn't exist.

It's been a lot harder [than predicted] for the individual sitting at a terminal to do. It requires a very high level of concentration. Your mind has to work at three times the speed to keep up with what the computer is telling you.

Electronic mail could eventually come about so that you don't need paper but it's a long way off yet.

Partly, some have happened faster and others haven't. The price and power of the computers has come down. The general practitioner is usually 10 years behind the cutting edge. The field is segmented, everyone is on different blocks [different specialisations within CAD].

Some, most of the short-term predictions are fairly accurate-a bit dubious about the long term. There is a lot of science fiction in there.

We asked if the practitioners had any major predictions for the future. There were two kinds of response-predicting more of the same and predicting a Gestalt shift. The common technological changes predicted were of increased speed and computational power, with further improvements in interface design. There were a range of changes to work practices predicted: more remote collaboration, computers everywhere, and improved integration of design, construction and material supply. The most common prediction was that virtual reality (in the form of improved animation and graphics techniques) would be the next major development. There was some mention of intelligent expert systems and electronic data models. Some practitioners focussed mainly upon the technical changes.

The speed of the boxes is going to make everything possible. Whether people are going to be prepared to invest the money in the software to make it all happen is another matter.

The trend will continue as it has gone in the last ten years and the systems will get simpler, and we will eventually eliminate the drawing board.

Speed and realism, virtual reality, will far exceed our present expectations. Whether that's a good thing I don't know.

Its being predicted for us. The front end people are doing it and the rest of us are just following along. You've got the manufacturers rationing the technology. Canon's A3 colour copier has been around for 5 or 6 years. They're not going to release it until they squeeze as much as possible from the black and white technology or until some one comes up with a competing product. I don't believe you should be leading edge. I think you should sit back and let someone else waste their money on being leading edge.

According to some practitioners there will also be structural changes to the industry.

Small firms will become just as powerful and able to compete with the large firms, and the role of the CAD operator will diminish.

Yes, I see a move that projects can be done in a more distributed way where the people working on the project are distributed geographically and the actual offices involved are much smaller. The team make-up will change from project to project rather than being the same in-house team for every project.

Problems Requiring Research

What are the problems that should be receiving research attention at the moment? We asked what (if anything) were the problems with computers in practice today. Many of the practitioners mentioned cost. Others mentioned standardisation, integration, speed and the ongoing need to upgrade.

Speed is always a problem. We're always quicker in thinking than the computers. Once you start in computers it's a never ending process of upgrading and updating.

People are saying "I'd love a computer that would do what I'm thinking." It's not a problem. It's just a wish. Standardisation is a problem that's difficult to solve.

Expertise is a bit of a problem. Budget is always a problem-being able to afford what you want.

The problem we have is that all the software packages function in isolation from each other. Our biggest limitations are software limitations. Ideally, we would build a package by taking modules from other packages. We cannot find software packages which fit exactly our needs because they are rigidly constructed and distinct from each other, which makes it difficult to mix and match to build something which fits our needs.

The complexity of the systems. More people would use them if they were easier to learn.

We asked what were the problems and issues ten years ago. Many of the issues raised in the previous question were repeated, such as cost and speed. Some also added the issues of getting suitably trained personnel, the difficulty in getting the machine to do anything at all, and people not understanding what computers were capable of. Other problems included the basic question of whether or not to get involved with computers, and if so, what system to use, adjusting to change as the technologies developed, and adapting oneself to the new technology.

We then presented several research topic areas-problems-to the practitioners and asked for their opinion as to which ones were the most worthy of research effort. Of the 15 topic areas we suggested one met with resounding support. This was management. *CAD and CAD services need to be managed better*.

Yes, I think most CAD systems aren't managed. The classic case is the [name deleted] system. It's put on someone's desk, they spend two weeks playing around with it, and the boss will say "OK they're trained now," when actually they're producing half the work that they would have manually.

They just use it as a drafting tool. They don't see its potential in redirecting the way that we approach documentation. We'll tend to produce buildings more like the way that we produce motor cars. We'll have standard designs and variations on those standards, and architects will produce the systems.

A close second was a category of problems, the first of which pertained to integration. *The problem is better integration between systems and the incorporation of data and communications standards.*

This is where it's all going-getting my system to talk to the consulting engineer's systems to talk to the client's real estate agent's system, his property manager... It's all about communication, communication protocols and data protocols. This is where the excitement is.

The way different packages communicate with each other is appalling. Data exchange standards should be a lot clearer and universal.

Of equal importance is the effective exploitation of information for automation. *The problems with design relate to the transfer of information down the line to the production/construction process. Computers make this a lot easier and more effective. We need accurate databases, modelling techniques, and automated design checking as well as better information standards.*

Yes, the construction industry wouldn't have a clue about what this stuff is all about. They're so reactionary. The impact on the built environment is going to be enormous. It's going to come through integrated databases. The design professional will leave the contractor behind in this regard. It's a bit like quantity surveyors. They haven't been too interested in automated quantities because a) *they* want to check them and b) they're not going to take any notice of input an architect has done unless they can see it and measure it. The amount of time that an architect would have to spend inputting the data over and above what he needs for his graphic production costs more than the quantity surveyor's fee. CAD systems can count but how do you measure the footings of the building and apply a different rate to one that is 600mm deep to one that is 1200mm deep? The architect has to explain it all. It's a myth this full 3D model in which everyone whips in and takes data out of it, but a disintegrated model is quite feasible and I think that's the way we're going.

Of slightly lower priority, it would appear that we need to research better design oriented computer systems. *Computer support for designers is poor. We need better systems created with the needs of the designer or professional in mind.*

To date it's been documentation oriented. Designers for various reasons haven't used it, and they haven't had the tools.

The problem is that computers require accuracy. You can give a computer inaccurate information but it will interpret that inaccurate information accurately, and designers can't think that way. My observation of designers is that it's very hard to make a computer assist them in a vague way. You can have a great idea and say to the computer "Does it fit into the space I've got?" but it's not going to give you the good idea to start with.

Its not so much the computer. Its the human side which needs to make the adjustments.

The problem is that not even the designers know what they want. So how can people give you what you do not know. The designers need to be educated in the computer field so that they become more aware of their needs.

There was equal agreement on the need to use computers to address the increasing complexity of design. *Design is complex and difficult. It is becoming even more so lately. We need computers to assist in this complex task.* It is interesting the phenomena that the practitioners identified as being the source of the complexity: increased expectations, new modes of working, and the increased complexity of ordinances and regulations. Firms tend to conceive of these issues as being extraneous to design.

I do not think that design has become more complex than it ever was, but I do see that computers allow us, by taking care of some of the complex tasks, to concentrate on other ones.

Very important-not because design is becoming more complex but because more is expected of us.

We also suggested that perhaps designers have to cope with more information now. *It is impossible to keep up unless we have information processing aids in the form of computerised catalogues, databases and electronic communications.* The practitioners also saw this as equally important.

The situation isn't much different than in the past. Most manufacturers use computers and have realised that they can now document on computer, and they've realised that people can take that data digitally. Managing that data is an important task. CSIRO [Australian Commonwealth Scientific and Industrial Research Organisation] has a role in developing an environment that makes the development of these products compatible across industry.

I do not think that we are barraged with more information than in the past, but the opportunity is there to access

information and it is just not being presented. I think it is insane that you cannot dial up a database and find out all the different types of glass available on the market.

Of slightly less importance was an attitudinal "problem" amongst practitioners. We suggested that perhaps *the potential of computing in design practice is not fully realised due to conservatism, ignorance and unwarranted scepticism.* One practitioner thought that it was an important issue but one that time, rather than research, would solve.

Of slightly less importance was the problem that *there is a major split in the design professionals between those who embrace the technology and those who shun it. This division is serious and needs to be broken down.*

Very Important-in the future you will not be able to design without a computer in the same way that you cannot design without a drawing board.

I think that division exists, but the people that shun it, that's their problem, and I am not interested in helping them solve it.

We also suggested that perhaps *little is understood about the role of technology in society and our relationship with it, and this needs research.* There was less enthusiasm for this proposition, but still the majority of practitioners supported it.

A lot of architects don't like the technology of their practice (even drawing boards). I think we need an understanding of the role of technology, and in the past architects have been pretty bad at catching up.

This is changing, society is much more aware. They all have TVs and home computers.

Very important-a lot of the time we are looking at computers through very old ways of looking at them, and if we can re-assess our relationship to them we are going to be able to make more satisfying use of them.

Amongst those who did not support the proposition that research is needed into our relationship with technology, one practitioner suggested that there is such a degree of awareness of computers that our relationship with technology is no longer an issue.

Not important-I do not think that is applicable any more. People are becoming more aware of what computers do and how they contribute to society. Our children need to be more involved with computers as they go through their education. They [computers] will have to become more economical for schools to afford them. As the children grow up, computers will become part of life.

Practitioners were more evenly divided on some of the other research areas we put to them. We suggested that perhaps *the problems of computing are mainly technical. We need better hardware, software and systems.* Those who disagreed with the importance of the area stated that it is going to happen anyway.

The hardware and software we have at the moment is very good and improving all the time. It is adequate for today's standards. We have come a long way in a short time.

The practitioners were also divided on the importance of making computing economical. We suggested that perhaps *the problems with computing are mainly economical. How do we make it pay?*

No, this is the big argument but it shouldn't be. It's economical if you're using it properly, but unfortunately 90% of people using computers are not making it pay and they don't even realise it. They've got CAD because they've got to have CAD because of the client or, if they're an engineer, the architects insist on them having it.

Only a minority agreed with the importance of the final four problems we listed. We suggested that perhaps *CAD and CAD services need to be marketed better. The pace of change is a problem for*

practitioners. IT is inflicting changes on practice at a rapid rate. There is little chance to take stock, assess the situation and ask if we really want to go where the technology is leading.

It's not that it is taking us somewhere that we may not want to go, but rather that we are travelling so fast that we are missing a lot of opportunities. I think we could be doing a lot more, but we do not have the time to sit back and think through all the opportunities and realise them.

We also suggested that perhaps *the ideological entanglement of technology with rationalism needs to be unravelled*. This problem met with some confused responses, but in general was not regarded as important by the majority of practitioners interviewed. Amongst those who thought it important, one practitioner gave a detailed response.

Very important-the reason that I think that is important, is that for a lot of lay people the idea of a computer is completely tied up with the idea of cold, hard-headed rationalism, and this actually prevents a lot of people from accepting or using the technology because they would consider accepting computers to be the same as accepting a cold, hard-headed, rationalistic approach to life. If we could break down the concurrence in people's mind of computing and rationalism, a lot of interesting things could happen with computers in practice.

We also suggested that perhaps *little is understood about the design process, and computers help our understanding*. The majority did not see this problem as important.

There is room to understand the design process better but the computer will not contribute to our understanding of the design process. It is only a tool we use in the design process.

I think that a lot is known about the design process, and I don't think computers will help.

Of all the research problems we posed, none were regarded as unimportant by an overwhelming majority of practitioners, and many problems seemed to divide the interviewees. It could be argued that the ordering given above should be reversed. Those problems for which the respondents were divided could be precisely those issues most in need of research. It could well be that half of the CAD community are unaware of the problems seen by the other half, and need to be persuaded of their importance.

We asked if the practitioners had seen any changes in what were regarded as important research issues ten years ago compared with now. We also asked to what they attributed the change. Most respondents considered the issues to have changed in emphasis rather than in kind.

I thought it would slow down, but every year there seems to be a new problem that needs addressing. Building models will give us a platform that design systems can benefit from.

Then we had to be evangelists, now we just do it.

Ten years ago it was still relatively new. It scared people. That has changed markedly because of the widespread publicity/education, ease of use and speed. Everything contributes to it.

You have the same problems as you did ten years ago. You're always limited to your budget restraint, finding the right type of people for the office and for a particular type of project. For a hospital project you have people who are specialised health planners but that doesn't necessarily mean that they are specialised at using computers.

The issue ten years ago was whether you wanted to do it or not. The issue today is how. The issue in ten years time will be those have and those that haven't. It's just the evolution over twenty years of going from a craft based office to a production line machine based office.

The whole ethos of computer use ten years ago was based on questions of centralised management of a big capital intensive resource and limiting access and so forth. Now all the questions have to deal with a sort of personal relationship

between a particular user and a particular computer and how that is enhancing their work or otherwise. In addition there are the social issues of how this change in work practice allows us to work in radically different ways. The most interesting question for me is how computerisation is going to help me work on projects in other countries whilst being in Sydney. How is it going to help me work with a team of people spread all over the place, the people that I want to work with and not just those who happen to be there? So I am interested in the way it is structuring my work life by increasing these opportunities. I am interested not only in the computing side but also the communication side.

The issues now are related to presentation techniques and design related activities. Ten years ago, it was how do we make them do what we did traditionally [as working drawings]. The change is due to enhanced skills and more powerful machines which can handle the technology.

Significantly different. The perceived limitations of computers have not been proven. The facility, speed and high level of complexity that it can deal with, and the increased acceptance of screen received information have dispelled these perceptions. This change has mainly come about by people *using* computers.

There has always been a concern about the effects of computers on society, which is still around. As the influence of the computer increases, the need to understand it's effects becomes greater. It has become much more commonplace now.

When we asked for further comments some practitioners took the opportunity to specify the kind of research they would like to see happening in this domain: specifically research that would help with coordination of IT, and the presentation but not the automation of design. Some practitioners also volunteered opinions on university research and how universities and practice could work together.

There are a lot of strengths out there in practice that are not present in academia, and at the same time there are a lot of things going on within the academic world of computing which are very interesting and would be helpful to practitioners. All the philosophical implications of computing that are being explored and discussed, and the radically superior way in which the academic world has set up its own computing networks and maintains these international communications, would in the private world be a radical innovation. What I do not see happening is any real kind of interfusion between these two domains of expertise.

Any kind of research program that, rather than maintaining an arms length relationship between the academic world and the world of practice, and that actually promotes a cross-cultural transfer of knowledge, I would think is very important.

Conclusion

The influence of computers on design practice is substantial. Computers are implicated in major changes to work practices. The work tasks of the practitioner are changing as a new equilibrium has been struck between professional tasks and those of draftspersons, middle management and secretaries. Some firms see operating a CAD system as a professional skill. It also appears that computers are used not only for administration and CAD drafting, but also in providing support during the design process. The environments in which computers reside appear to be different than those occupied by drawing boards. It is also apparent that projects in which CAD is used are managed in subtly different ways to convention projects. CAD has changed notions of where accuracy and precision enter into the design process. Computers also affect the dynamics of communications within the office. They are also affecting the way practitioners communicate with clients and consultants. There is an interest in teleworking and other experiments in spatial mobility amongst practitioners, though this change is only just starting to be felt.

The profile of firms is changing and some practitioners believe the viability of small firms is enhanced by computerisation. Some firms have also cast themselves in a totally different light due to computerisation. Some have diversified into new areas, such as multimedia production, or moved into the role of custodians of databases. Practitioners seem more resilient to the pressure of changes now than they were ten years ago. There is more folk wisdom about now for coping with problems, better support networks, and the equipment and software is easier to use and more powerful. Computer components and software are more modular, interchangeable, and the individual components are less expensive. Even though a whole system may be a major expense for the firm, the individual components are not. Acquisitions can be made incrementally and on a trial basis. This has made a major difference to how IT is appropriated in practice.

Practitioners who use CAD are very interested in the potential of computers and what the future holds. Computers are not used impartially, but, as the responses to our questions about trends indicated, are also caught up in hopes and expectations for a bright and prosperous future of better integrated computer systems and environments more attuned to the needs of designers.

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References

Bjørn-Andersen, N. 1983. "The changing roles of secretaries and clerks," in *New Office Technology: Human and Organisational Aspects,* Otway, H.J. and Peltu, M. (eds), Frances Pinter, London, pp. 120-137.

Coyne, R.D. 1989. "The implications of computer use in architecture Schools," *ADTRA: Journal of the Architectural Design Teaching and Research Association,* Vol. 1, No. 2, pp. 5-12.

Crozier, M. 1983. "Implications for the organisation," in *New Office Technology: Human and Organisational Aspects,* Otway, H.J. and Peltu, M. (eds), Frances Pinter, London, pp. 86-101.

Cuff, D. (1991) *Architecture: The Story of Practice,* MIT Press, Cambridge, MA.

Danziger, J.N. 1985. "Social science and the social impacts of computer technology," *Social Science Quarterly,* Vol. 66, pp. 3-21.

Forester, T. (ed) 1989. *Computers in the Human Context: Information, Technology, Productivity and People,* Blackwell, Oxford.

Gotlieb, C.C. and Borodin, A. (1973. *Social Issues in Computing,* Academic Press, London.

Gutman, R. (1988) *Architectural Practice: A Critical View,* Princeton Architectural Press, New Jersey.

Kling, R. and Iacono, S. 1988. "The mobilization of support for computerization: the role of computerization movements," *Social Problems,* Vol. 35, No. 3.

Long, R.J. 1987. *New Office Automation Technology: Human and Managerial Implications,* Croom Helm, London.

Marien, M. 1989. "IT: you ain't seen nothing yet," in *Computers in the Human Context: Information, Technology, Productivity and People,* Forester, T. (ed), Blackwell, Oxford, pp. 41-47.

Mumford, E. 1983. "Successful systems design," in *New Office Technology: Human and Organisational Aspects,* Otway, H.J. and Peltu, M. (eds), Frances Pinter, London, pp. 68-85.

Olley, H. (1992) *1990 Profile of the Architectural Profession,* Royal Australian Institute of Architects: National Division, Canberra.

Otway, H.J. and Peltu, M. (eds), 1983. *New Office Technology: Human and Organisational Aspects,* Frances Pinter, London.

Radford, A.D. and Stevens, G. 1987. *CADD Made Easy,* McGraw Hill, New York.

Stevens, G. 1989. "The social construction of computer-aided architectural design," *ADTRA: Journal of the Architectural Design Teaching and Research Association,* Vol. 1, No. 2, pp. 51-56.

Wainright, J. and Francis, A. 1984. *Office Automation, Organisation and the Nature of Work,* Gower, Aldershot, Hampshire.

PART III

The Internet

CMC in Design Firms

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We examine how the introduction of computer-mediated communications (CMC) technologies, such as the Internet, affect design firms. We interviewed a diverse sample of the small but growing number of practitioners from around the world who use the Internet in their day-to-day operations. The interviews were conducted using the Internet. We found that certain firms are redefining themselves in terms of their entrepreneurial endeavours, as processors of texts, as collaborators, and as players in the global arena. We discuss these phenomena in the light of the philosophical consideration of the way technologies disclose features of a firm's practices. Disclosure displaces need as the means of understanding the relationship between technology and practice.

Computer-mediated communication (CMC) is a class of computer-based technologies to assist people to get in touch with each other (Hiltz and Turoff, 1993), a facility taken for granted in universities since the inception of the Internet and electronic mail (email) in the 1970s, and now finding its way into the business world. What are the impacts of this emerging technology on design practices? We argue that any technology introduced into practice is implicated in various transformations of that practice. CMC amplifies, re-defines, re-orients, brings to light, or generally "discloses" certain aspects of that practice. Practice in turn reveals aspects of CMC. We show how CMC is implicated in the way certain firms are redefining themselves, focussing on the firm's view of itself as an entrepreneurial enterprise, a handler of texts, a collaborator, and a player in the global arena. Prior to this analysis, we review how firms use CMC and how CMC has found its way into the office routine.

We investigated the small, but rapidly growing number of design-oriented firms using CMC by interviewing a representative sample of nineteen practitioners (mostly in architectural firms) from around the world-from USA, UK, Australia, Venezuela and Italy. We distributed a "call for interest" on the Internet, made contact with respondents via email, and interviewed most of the respondents on-line using the Internet. The firms ranged widely in size from one person practices to 650. Six of the firms we investigated had under five staff. The people we interviewed included CAD (computer-aided design) specialists, systems administrators, directors and principals. The interviewees varied in their experience with CMC. The more experienced had used it for ten years, most had from two months to three years experience, and one had only three weeks experience. Several of the practitioners regarded themselves as experienced users, but most said modestly that they were at the stage of "just exploring."

To date, most studies into CMC have been field or laboratory based studies, and succeed by isolating aspects and behaviours of on-line communication from the vagaries of practical contexts (e.g. Hill, 1982;

McGuire, Kiesler and Siegel, 1987; Hiltz and Johnson, 1989; Matheson and Zanna, 1989, 1990; Dubrovsky, Kiesler and Sethna, 1991; Dennis and Valacich, 1993; Valacich et al., 1993, 1994). Constructs, such as social presence (Short, Williams and Christie, 1976; Rice, 1984; Walther, 1992), lack of social context cues (Sproull and Kiesler, 1991) and media richness (Trevino, Daft and Lengel, 1990), support the notion that CMC is best thought of as a task-related and/or problem-solving environment. Some studies in organizational contexts, search for reasons people adopt or "use" CMC, frequently arriving at social influence or cultural construction explanations (e.g. Fulk, 1993; Steinfield, 1989; Schmitz and Fulk, 1991).

The picture of CMC painted by summing laboratory and field studies is incomplete. The validity of laboratory studies is problematic for two reasons. First, most subjects are an atypically captive audience. Experimental subjects do not reflect the CMC environment. Second, an almost natural inclination of experimental design is to contrast CMC with a face-to-face standard of comparison, which may be misleading. Field studies also are problematic as they are usually intraorganisational and thus do not offer global explanation of communication in praxis.

Our study is qualitative and overtly interpretive, attempting to capture insights into CMC in the practice context, with all its variation, through structured interviews. The best insights came directly from the practitioners themselves, so in this article we rely substantially on verbatim reports (edited) to corroborate the patterns that emerged. Our approach borrows from studies in ethnomethodology (Garfinkel, 1967), theories of metaphor (Lakoff, 1987), and contemporary understandings of philosophical pragmatism and phenomenology as articulated by Dreyfus (1990) and by Coyne (1994) in relation to information technology.

CMC in practice

What can practitioners do with CMC? The most prominent vehicle for CMC is the Internet to which commercial users generally connect via a telephone modem. Very few of the firms we investigated had a direct link or a dedicated telephone line connection to the Internet. From a modem you dial into a service provider, such as Compuserve, AppleLink, America On Line (AOL), the Microsoft network, Pipeline USA, or a local university, and the connection to the Internet is made from there. The narrow bandwidth of telephone modem connections is limiting, and the practitioners we interviewed used the Internet primarily for text handling as opposed to on-line graphics. None of the firms yet had direct connections through the fibre optic networks now installed in most cities. Firms have to pay for CMC services, though some of those we interviewed only had to pay for a local phone call. The majority paid commercial rates, which are well within the budget of any practice, comparable to telephone rental charges. The cost is about the same whether they are using Internet or Compuserve, and costs are comparable whether in the US, UK or Australia, though the US is a little cheaper.

The Internet, and its commercial supplements, comprises a range of services. All the practitioners we interviewed used email (sending messages to any other user anywhere in the world), Archie (which allows you to browse on-line databases), Gopher and Fetch (for downloading files from some publicly available server to your own computer), bulletin board systems and discussion groups (dynamic directories, daily digests or individual email messages from people talking on particular themes), ftp (which stands for "file transfer protocol" allowing you to transfer data to/from someone else's computer), Telnet (for connecting to another computer and running its software), Chat/Talk/IRC (Internet Telay Chat) (systems for real-time text-based conversations, used in our interviews), Conference Room facilities (based on the same idea but making substantial use of spatial metaphors), and Mosaic and Netscape for accessing the World Wide Web (WWW). The WWW provides full interactive graphical and multimedia communications, and access to a vast pool of distributed on-line resources. The practitioners typically said they used these services for email, accessing technical support for their computer systems, and finding people with common interests. Use of the WWW was limited because of the slow speed of telephone modems, but it was used by some to find out about individuals and firms (through "home pages" they create to advertise themselves), and for downloading the latest computer software patches (enhancements and bug fixes) and add ons.

CMC and the office matrix

CMC technologies fit within a matrix of related office communication technologies and practices that researchers such as Travino et al (1990) identify as varying along a continuum of media "richness," including face to face verbal communication, formal and informal meetings, the distribution of hand-written and typed memos, informal scriblings on yellow adhesive "post-it" labels, intercoms, internal phones, courier services, the postal service, and formalised written communication protocols such as those afforded by "quality management systems." CMC also fits within a matrix of related office communications technologies, such as computers, fax machines, portable phones and pagers. Some of the practitioners we interviewed used portable computers as part of the CMC matrix, for working from home, connecting to the office computer when at home or out of town, for presentations out of the office, and for working with clients. Some also used mobile phones to keep track of business partners, keep abreast of business developments, maintain contact with clients, and during site visits. One practitioner carried a hand held (notebook) computer on trips, mainly for writing memos and faxing. Only one practitioner used a pager. A couple of practitioners mentioned direct modem to modem connections for data transfer and computer hookup to the public library and municipal offices. One mentioned lease of an ISDN (International Subscriber Digital Network) line (a dedicated phone line). None had used video conferencing, neither desktop video conferencing nor via a video conferencing centre. A couple of people were looking into it, though some remarked that it was too expensive to date.

There are three features of this communications matrix that pertain to our study. The first is that these systems of communications contain redundancy. The sphere of applicability of each of the technologies overlaps in certain ways, such that if the email system breaks down then there is always the telephone or fax as a backup. Second, the communications technologies are inconspicuous and ubiquitous, used by choice and on demand. Once they are installed, or access is paid for, then they form part of ubiquitous communications networks and can be used without deliberate planning. As with the telephone, with CMC there are no heavy capital investments, it is less the focus of special policy meetings than CAD or other conspicuous office technologies, and CMC seems to make little difference to office layout. Third, each technology provides useful analogies or metaphors for the others. So to use email is a little like using the fax machine, though with important differences. Such comparisons assist the practitioner in understanding a technology. The advantage of this analogical connection is that no technology seems entirely new when introduced to an office, even for the first time, and office practices do not always have to be radically altered to accommodate the new technology. Certain technologies seem to pave the way for other technologies and their acceptance, much as telegraph paved the way for the telephone, and the adding machine "prepared" offices for the early computers. Aspects of CMC fit seamlessly into the communications practice of the firm. Its effects are gradual and long term. In this sense, CMC provides less of a shock to the firm than technologies such as CAD, where analogies with drawing board practice are more alien, and which radically alters work practices, office layout and even the staff profile of the firm. The involvement of CMC in transforming the office is perhaps more surreptitious.

The extent to which firms regard themselves as dependent on CMC is a useful indicator of the extent of its absorption into practice. Those we interviewed were equally divided on whether or not they were now CMC dependent. One regarded CMC as a supplement to the phone and the fax machine so he does not do anything critical with it. For another, CMC was only a hobby. For some, CMC was indispensable for the firm to be competitive, in other words gaining clients: "I depend on it. I have met new clients over the net." One practitioner depends on CMC "to gain access to information I consider strategic. Information leads to knowledge which is power, or a competitive edge shall we say." For another practitioner: "I guess in time it will become a habit that is hard to break." For some, CMC was woven into their way of working on projects. One said: "As an information resource I find it indispensable. I've used it for interactive specification writing sessions with consultants in San Francisco. I don't know how I communicated before without it-sort of like what we say about the fax machine sometimes. I find the email capabilities to be my crutch and a godsend." According to another practitioner: "I depend on it for literature searches"; and another: "I depend on email to work co-operatively on complex documents, with my subcontractors in Los Angeles and Scotland, both of whom bring special skills to bear."

Where it is used, CMC seems to involve everyone in the firm. About half the practitioners we interviewed said everyone uses it. Some singled out professional staff, and in a couple of cases only administrative staff use CMC. In one medium sized firm the only user was the interviewee. A couple of firms said that they had no secretarial support as they do all their own administrative work. This pattern of usage demonstrates the surreptitious ease with which CMC can be absorbed into office practice, initially with only gradual alterations to work roles.

However, new work practices are emerging with the introduction of CMC. CMC affects how practitioners use their time, mainly by taking up a lot of it. Practitioners seem to dedicate certain times of the day to using CMC, such as at the start of the working day, just before going home, or in the evening from home. One practitioner had a "web browser" (software to connect to the WWW) open all day and used it when needed. For one practitioner WWW usage was in the evenings as that was when the lines are less congested. Email was used any time during the day. CMC use can take up a lot of time. While a couple only used CMC two to three times per week, one practitioner used it for four to five hours a day, though this had recently tapered off to about one hour. Answering email and browsing for information clearly provides a degree of enjoyment, or at least absorption, for the busy practitioner.

Unlike other technologies, such as CAD, using CMC does not make heavy demands on the expertise of the user. Using CMC is not technically difficult and does not require extensive training, although experience is required to know how to use it effectively and where to find useful information. Services, sites of information, and the technology itself are changing all the time, so one has to keep up to date, or know who to ask about the latest developments. At the time of this investigation, the World Wide Web had only been around for a few years, and "network aware" computer applications programs were just emerging.

The terminology of CMC is also evolving at a rapid rate. CMC seems to bear the trappings of a populist cultural movement as well as a technology, comparable to pop music culture, and hobby cultures, such as citizen band radio in former times. The terminology changes from year to year and is laced with its own idiosyncratic qualifiers and signifiers. One of the practitioners we interviewed lamented that the technology seems to have more impact on the younger members of the practice, who are more open to the changes. This bias towards the young may also reflect the populist nature of aspects of CMC culture. Participation in CMC requires familiarity with both the technology and its language. This particular cultural engagement provides a new dimension to office practice.

Some practitioners provided evidence that CMC challenges other forms of internal office communications. They found CMC a convenient way of communicating within the office. According to one practitioner CMC is used "oddly more than one would think. It does seem so much more convenient and even appropriate in a professional setting. It enables one to get down to what counts in this environment and not have the communicative signals all crossed with a host of other forms of communication." One firm used a local area network communication system (Snapmail), "to replace that blizzard of yellow post-its that seems to proliferate otherwise." Some found CMC communication particularly convenient when the business of communication is CMC. Sometimes email is convenient for sending data, such as email addresses or WWW URLs (electronic addresses of files on servers around the world). But for the majority of those we interviewed, CMC was not used for internal communications. For many this was apparently because the firm was too small or computer workstations were not yet widely distributed in the organisation.

CMC also fits within the practice of drawing and CAD. Most of the practices we investigated were involved with the production of drawings, but most used the fax machine for transmitting drawings electronically rather than CMC. One practitioner had found the transmission of CAD documents too cumbersome. But some already used CMC for drawings: "At work we have transferred drawings to and from architects which are attached to email." According to another: "This is the main form of use for us. Both drawings and 3D models, and formatted long text documents." Most wanted to use CMC for transmitting drawings in the future, which

would introduce new office practices, and would radically alter ways of interacting with clients. According to one practitioner: "I'd like to set up my own home page on the WWW (when the price drops). I'd love to be able to have clients log in, and pick from houses I've already designed. I'd have my house plans up there, so that they can look over the plans, and see the elevations before they download them. Then if they like what they see they can order it, and I would somehow transmit to them the whole set of drawings."

In summary, many of those we interviewed reported that their work role or work habits had changed in some way due to CMC use. CMC is implicated in the changing nature of office routine and the issues of running a practice, but the major changes come about when we investigate how CMC is implicated in the way firms see themselves. Our premise is that any new technology, such as CMC, discloses aspects of the practice in which it is situated. We turn now to the substantive changes in terms of entrepreneurship, text handling, collaboration, and globalisation, and the evidence for these changes gathered from our examination of practices using CMC.

The CMC entrepreneur

This is an interesting time for the fortunes of CMC in practice. At the time of writing, CMC is *not* yet ubiquitous in the business world, including architectural practice. CMC users are in the minority, and as such constitute an interesting group. For some of those we interviewed CMC is merely a means to an end, but most were clearly involved in it because it intrigued them. The process by which we selected the interviewees ensured this to some extent as we canvassed interest through Internet newsgroups. But our interviewees were typical of CMC users in practice, which is currently primarily in the hands of CMC hobbyists, adventurers, practitioners keen to try something exciting and new, interested in where the technology is heading and what are its implications. These people are not only visionaries, but are practical, with a strong sense of competition, and are concerned about long term financial viability. Before CAD became commonplace, early CAD devotees had a similar orientation. As devotees, the opinions of these CMC practitioners are developed and reinforced through their involvement in various discursive communities, sustained by publications such as CompuServe, Microsoft, PC World, NetGuide, PC Magazine, Personal Computer World, PC Week, World, Wired, MACUser, MAC World, Internet, Multimedia), the Architect's Journal, Architectural Record, Progressive Architecture, Building Design, newspapers, and of course on-line communications through the newsgroups such as "alt.architecture," "comp.inforsystems*," "comp.cad.autocad," NetNews, the WWW, and briefings with consultants and fellow users. Some CMC users also imply they have access to "the source," to key development personnel, such as "scientists at Apple Computer Corporation headquarters."

The adventuring orientation emerged when we asked what prompted the practitioners to start using the Internet. A few made the obvious appeal to the need to communicate or gain access to information. For some there was a progression from a particular use that was obvious to another use disclosed by the technology itself. One practitioner started by using email then got involved in library searches via Telnet: "I am currently designing an electronic lock for large manufacturers. I searched about six different article databases to see what the state of the art is." One person wanted to get into CMC to keep in touch with a friend overseas. Other uses developed from this. For one practitioner CMC harboured potential as a marketing tool, and eventually generated five to six email queries per week. Another firm said they had won two jobs so far through the Internet.

For other practitioners the Internet fitted into an ethos of networking, that already imbues the world of entrepreneurial practice: "I'm always interested in networking-tapping in to what resources are available." The networking ethos is also endemic (perhaps "pre-wired") to the technology itself in some cases: "It was preloaded in my computer when I bought it." For some there was an inevitability about adopting CMC. CMC services became available once the practitioners became involved in using computers and CAD. CMC is a logical extension of current computer usage. Some suppliers, such as AutoCAD, also actively encourage the use of CMC, with on-line product support. Some suppliers and user groups offer on-line

software updates, modules and enhancements. One practitioner was responsible for developing IT policy for the firm, which inevitably involved an investigation into CMC, and led to them adopting it. The promotion of the computer networking ethos is also abetted by the media. One practitioner simply "read a lot about it and it sounded interesting." Others were introduced to CMC through colleagues, friends, family or as students. One practitioner "caught the bug" and got a modem for his own machine. These rationales highlight the entrepreneurial propensity for making connections (that it is 'who you know' that is important), the communal nature of CMC use, its minority status making you part of an elite enterprise, and the sense that soon it will become very big and important.

It is characteristic of entrepreneurs to be articulate about the issue of resistance. Why is there a resistance to CMC? The interviewees cited lack of the right hardware and software, finding sufficient time to further explore CMC, financial restrictions, and poor reliability. The practitioners we investigated were devotees, but the other members of their firms were not necessarily so committed. Several mentioned other people as the source of resistance, particularly clients. According to one practitioner, most innovations are client led, and there is no demand from clients for CMC: "My current clients and consultants are even bigger neo-Luddites than me." A further impediment was management. According to one interviewee there is "little understanding of the potential of access by senior managers." The technology is clearly at an early stage for wide adoption, though things are changing rapidly. One practitioner pointed out that at the moment the interface to the Internet is mostly Unix or Unix-like, which requires learning. At the time of writing, most practitioners do not enjoy the same quality of access as universities: "most of the people at the other end are accessing the net through some kind of gate (either Compuserve, or a departmental email system) which means that we cannot use functions such as Talk and are restricted to mail only." Even though these are legitimate concerns, there is a sense in which the CMC community thrives on this resistance. If CMC were easy then everyone would be using it, and it would lose its elite status. If they were successful in persuading everyone that it was such a good thing then it may be less useful as a means of gaining a competitive advantage in the market place, and less interesting for them, though many may be happy to move on to some new challenge, or some other aspect of the technology that needs exploring.

A further aspect of the entrepreneurial spirit was the enthusiasm by some of the practitioners to diversify their practice, at the moment and also in their plans. One practitioner hoped to connect with his father, who was an engineer, because they are "starting a building code consulting business and he works in Boston." One of the interviewees was involved in the organisation of a conference via the Internet: "I have participated in any number of projects where we had group collaboration via CMC-like conference planning. We were planning a conference in total, program, speakers, logistics, scheduling, etc, all remotely amongst a group scattered across the USA." Eventually CMC will produce more flexible staffing arrangements: "It will allow some employees to become sub-contractors to their former firms." Information technology provides opportunities to explore new building types and presents new design issues: "We design the spaces to accept the use of CMC devices in many instances."

The entrepreneurial practitioner is interested in profits, and most indicated that their practice was more profitable through the use of CMC. CMC would only be unprofitable if it required a big investment, but unlike CAD ten years ago, it is relatively inexpensive to set up. Like CAD, "CMC pays when changes are required, especially on a large scheme." One practitioner thought that they were much more profitable with CMC: "We are doing quite well thank you. By keeping the juggling game of CMC implementation and profitability going we have been very fortunate." One practitioner thought that CMC enabled the firm to extend its "reach to a larger client base." In the light of the recent UK recession one practitioner cautioned that it is not a matter of "achieving 'more profitability' but rather a matter of trying to achieve 'some profitability' which is the issue." He stated: "We need to be more efficient just to stand still. One can only expect so much productivity from staff, one can only reduce ones overheads so far. The rest is the result of good management and more effective use of IT to improve efficiency." Some cautioned that "it is a competitive business, and one's competitors will also soon use CMC. When competition is taken into account it may well be that the whole industry is no more profitable." For another practitioner it was "less profitable when you take the whole computing enterprise into account-CAD, videoimaging, etc. Primarily it

is because we are exploring new technology and we don't know how much it will cost." Most regretted that they would have to reduce their use of CMC if the cost rose sharply, though some regarded it as unlikely that costs would rise, or thought that they would be able to find cheaper alternatives to the usual service providers, such as paying for a direct modem link. The entrepreneur will always find a way.

Entrepreneurs seem to seek out those who support their own enthusiasms, selecting consultants and collaborators on the basis of whether they have access to CMC. But the entrepreneur is also persuasive. Several practitioners said that if there was little choice then they would seek to "convert" the consultants, who would be dropped if they did not catch on. One firm even claimed to have computer literate plumbers working with them: "you must be computer savvy in order to work with us. We have plumbers that must be computer literate and have a modem in order to bid on our work. They are out there-more than most architects that have this technology. It gets scary." One practitioner said that selecting consultants and contractors on the basis of CMC access would "limit the available pool of otherwise qualified consultants. But in the future, as the world becomes saturated with CMC as it did with the telephone, it most certainly will become a critical consideration or prerequisite for business."

This disclosure of practice as an entrepreneurial enterprise extends to three other areas that assume new prominence in practice. The CMC entrepreneur is also an author, concerned with textual material and its dissemination. The new entrepreneur is part of an elite community that thrives on collaboration through electronic means, and the practitioner is ambitious to extend the reach of the firm in the global arena.

Text and technology

CMC discloses design practice as intimately involved with texts. In the electronic age, the concept of text has been generalised to the more abstract notion of "information"-that texts contain information, and drawings can contain information as well. As we discuss elsewhere (Coyne, 1995), contemporary language philosophy suggests that to talk of information content is simply to refer to another textual notion, that of the proposition, which for some purposes is a more precise form of a textual statement. The primacy of the conduit metaphor, that texts *contain* and transmit information, has been displaced in some quarters by the more prosaic notion that there are only ever texts, and translations between texts. There is value in regarding CMC, and computers in general, as concerned with the manipulation and transfer of binary signals, that are translated into text for certain purposes. By this view it is not helpful to think only in terms of meanings or information coursing through computer networks. Texts and pictures mean what they mean by virtue of our capacity to interpret them, and it is primarily texts and pictures that are exchanged through CMC. For our purposes here, "information" is just another word for "text."

Architecture is ostensibly concerned with buildings, drawings, models, the visual and kinaesthetic experience of space, visual representations, and an engagement with physical tools and materials. Texts are secondary. This priority emerges in architectural education and training, particularly in the discourses of the design studio. The visual and kinaesthetic is prioritised over the verbal. Yet much of architectural practice concerns the written word-annotations on drawings, correspondence, reports, schedules, and specifications. The justification of a design proposal is as much a matter of skill with words (often written as well as spoken) as with drawing, and many prominent architects have been writers (Le Corbusier, Peter Eisenman, and Bernard Tsumi are prominent examples), or their fame was inextricably accompanied by the writings of others, such as the academic Sigfried Gideon as an apologist for the work of Le Corbusier. As shown by the responses to our questions in the practice interviews, CMC brings the text-based aspects of design practice to the forefront, and is implicated in their transformation. The mainstay of CMC is the Internet, which grew to what it is today through the enterprise of academics, particularly in the USA. So it inherits the legacy of Enlightenment concepts of free speech, the transformative power of the printed word, and the mobilisation of an informed and politically aware public. The whole enterprise belongs to a written verbal culture. Were the Internet to focus on communication via real-time video or sound technology rather than the printed word then Internet communities would change in character. Analogies are frequently drawn between the nature of

CB (citizen band) radio communities and groups that use the Internet, but as CB radio involves speech (ie aural communication) and the Internet involves writing they involve different kinds of communities. For many reasons, CB radio never attracted and sustained professionally-oriented university-based intellectual communities. Were the Internet to change from text to visual (video) and aural communication rather than text, and were it to be as ubiquitous as the telephone or television, then the profile of its users may change dramatically.

Our interviewees highlighted the renewed written-verbal orientation of the firm in several ways. First, the practitioners expressed a renewed regard for the notion of information as central to practice: "The role of an architect has transformed into being an information manager of a project, not just a leader but a resource of information." To the list of metaphors of a professional as expert, artist, scientist, counsellor, mediator, and so on, CMC vividly demonstrates the emerging metaphor of the professional as an on-line source of information and as information manager. Second, since the introduction of computer wordprocessing, practitioners have taken over the role traditionally concerned with text processing, the secretarial role. CMC seems to advance this trend-only a few of the small firms we investigated still employed secretarial staff. Third, is the renewed regard for consulting. To engage in consulting rather than a commission is commonly to undertake an advisory, and usually a verbal, role. The product of a consultation is frequently a written report of some kind. One of the practitioners thought this role was increasing: "I hope it [practice] will veer towards a consultant role in addition to the traditional roles of the architect. I see lots of people on the Usenet [newsgroups] looking for architectural guidance and information on products, spatial arrangements, construction, etc." One practitioner hoped to do more consulting in addition to architecture. Another practitioner saw his role as that of the "moderator, communicator, intermediary," as he managed the messages connected with a collaborative project. Fourth, CMC on the Internet has defined new roles and designations that are variants of roles connected with text-based publishing. There are the news group moderators, editors of on line publications, senders, recipients, authors, readerships and browsers. Practice that uses CMC is continuing this chain of usage and taking over some of the metaphors of publishing and CMC.

Fifth, CMC fosters a highly reflexive community, arguably a product of highly literate text-based communities, and design practitioners who use the technology participate in this reflection. As one can see from various indexes of activity on the World Wide Web, a substantial part of CMC communication is about the net, and about the nature of the communities that use it. Our on-line interview survey provides a further example of this reflexivity. CMC has introduced new areas of specialised knowledge and expertise into practice, and the medium itself provides support for the new skills acquired, with on-line support available for almost all areas of computing. The telephone provides a good example of a medium that does *not* support self-reflexive communities. People using the telephone rarely talk at length about telephones, or about the nature of the communities that gather around their use. The text-based nature of CMC contributes to its reflexivity, and further sustains the need to communicate, and to use CMC to do so. CMC amplifies a trend towards reflexivity that sociologists such as Giddens (1990) tell us are characteristic of late modern society.

Sixth, and most importantly, as a technology of the text, CMC renews the idea of practice as a decision-making enterprise. According to language theorists such as Austin (1966), language utterances do not so much describe situations as make things happen. The archetypal sentence is one that constitutes an action-"With this ring, I thee wed" uttered in the appropriate context is instrumental in uniting two people in marriage. To declare that an object is a table is to participate in a community that makes it a table. This pragmatic strand to language understanding is further sustained by the popular corporate ethos that asserts that people who "control" words are in control of the situation, which is to say, more in control of themselves. The practitioners provided ample evidence of this linkage between text and control: "I think maybe it [CMC] has forced me to respond faster, and also (despite my lack of typing skill) to think more about what I say, and has made me write better, because it is writing rather than talking mostly." According to another practitioner control through information held the future to the professions-as the source of information you are more in control: "Adaptation to a more information source based practice rather than an information

research based practice seems to be the course we are taking. By being the information resource for a project, you are a valuable commodity. If architects can control the information and treat it as equity, they will control the construction project and remain in their rightful place of the project leader." CMC also provides an opportunity to relinquish the details of certain aspects of a project to others: "I spend more time structuring work, preparing it, etc for people at a distance. This in turn means that I do less work myself, take less responsibility for particular jobs. More jobs get passed off to someone else, but then I have a larger role in structuring those jobs."

Most practitioners claimed that CMC improves the decision making process. They said it speeds up decision making, renders it more efficient, helps you organise information, provides more resources, provides access to people to talk to, enhances writing skills, makes it possible to research products and services without leaving the office, and enhances confidence. How does CMC bring this about? According to one practitioner, with CMC "decisions have to be written. No hand-waving is allowed. So the decisions get made more deliberately. Is that better? It certainly accords better with classical project management, and it does also feel better (fewer loose ends, fewer 'lazy' decisions)."

Decision making requires good information, and CMC gives the practitioner access to it: "Now when I need something I look for documentation on the Internet, I ask for help on Usenet and then I decide. It takes more time but I can achieve better results in this way." CMC certainly helps if you want information pertaining to the computer world: "you know what is going on in the computer world. You don't fall behind due to lack of information." CMC apparently improves decision making by allowing a good flow of information between practitioner and clients: "We send clients preliminary designs and schematics for approval. They send back comments and questions." CMC seems to make the information processing aspect of decision making practice more obvious, but it also renders the inclination of practitioners to withhold information more apparent: "With CMC, it is more obvious that you are withholding valuable information. You have to deliberately not answer a written query."

Several practitioners implied an elevated awareness of the ability to be precise in processing information and making decisions. The concept of precision in building practice dates back as far as the introduction of measured drawing and drafting. The use of the computer for drafting and modelling is an extension of Enlightenment concepts of objectification, an extension of industrialisation into the building process, and a general quest for mastery and control of nature and materials. According to social commentators such as McLuhan (1962) such trends were already in train with the advent of writing, and reached their apogee with the invention of the printing press. By facilitating the infinite reproduction and distribution of thought, the culture of the printed word reinforces the concept that truth is a matter of precise correspondence between the printed, or digital, word and some state of affairs in the world. Ameliorated by pragmatic concepts of language (such as those of Austin [1966] and Derrida [1988]), the privileged relationship between texts and precision is still apparent. According to one of the interviewees: "[with CMC] I am more efficient, capable of responding faster and more accurately." For another: "It improves the accuracy and thus saves time and money. We are better at [what we] do-being creative problem solvers. It makes for better architecture." According to one practitioner the future lies in the better and more accurate processing of information: "improved integration among different disciplines, better coordination of information, the ability to respond even faster and with greater accuracy, even more extensive use of cut and paste techniques from a variety of sources, and the ability to 'talk' with specialist subcontractors more directly."

However, CMC brings to light the added possibility of error. It is an immediate medium, and one can act in haste: "There can be a tendency towards impulsivity. One must carefully consider." According to another practitioner: "Perhaps some decisions are closed off sooner than necessary." There is also a treadmill effect. There is pressure from clients to perform ever faster, and competition between firms "has necessitated making decisions faster than the next guy." Unfortunately, "clients get used to the service and want things faster still. Sometimes it's like being on a treadmill!" CMC seems to invest practice with a renewed concern with what it is to be careful and precise, and the dangers of acting in haste.

Accuracy and efficiency also pertain to time. Because it is possible to transmit information instantly CMC apparently allows designers to work on their designs up to the last minute: "It gives us more design time so we can send a drawing at 8:00 am instead of using a Federal Express mail service the night before." CMC also seems to make the practitioner more responsive: "It might make it more responsive (ie faster.) We can more easily adjust resources to workload." One practitioner suggested that as the technology becomes more widespread, "coordination with consultants will be greatly improved, resulting in the optimization of the construction process."

Perhaps this focus on texts is a distraction from the real concern of the design practitioner, the built product. We asked if CMC has any affects on the quality of the buildings or structures produced by the firm. A few said CMC was of no consequence on the designed product, but some pointed to the improved product and service provided through the ability of CMC to convey information: "CMC affects my designs indirectly, mainly through knowledge gleaned from literature searches, unless you also take into account changes to better match the customers needs that you only become aware of through better communication." According to one practitioner, better information leads to better service, and better design: "Everything I do, or learn, or whatever, affects my buildings and makes them better, so the use of CMC is no exception." CMC even provides a means of moving out of one's professional circle and gaining better insights into clients' needs: "Sometimes I think I get a better understanding and appreciation of my clients after hearing people trash architects in the newsgroups." Of course, CAD and CMC also conspire to allow better visualisation of the finished product before it is built, and the transmission of the computer generated image. The technology provides: "better ways of viewing an end product before it's built-exploring alternative ways of constructability."

The focus on texts also brings to light the matter of security-the obvious prospect of "messages being misdirected or intercepted." According to one practitioner: "This is a real issue. There have been occasions when I have sent what I thought was a personal message and had it forwarded to the entire listserve [news] group. For myself, I use the ethical considerations for email I would for any written and verbal communication. I treat them as personal, and seek permission to make them public should I need to." According to another: "Any item we wouldn't feel comfortable faxing would never be sent this way." The other problem is "people breaking into the firm's file store, etc." For one practice: "Once a person logs on, he can pretty much have access to anybody's drawings here, because we are all architects and we are all helping each other's projects. We have an access code to get into the machine, but the log on thing is something that is set up in your name, so if you know my name and the code I use you could log on too. Other things are kept locked-accounting files, marketing files [for instance]." One firm had "Firewalls" (access points that are impermeable to outsiders) built into their dial-in server, they use passwords that are changed weekly, and they are as secure as a "Sherman tank." Personal security is also an issue: "I make it somewhat difficult to actually find me, as my street address is not published in any phone book or directory."

One firm had taken extensive security measures, but not for email: "We have programmed our CISCO router [for connecting parts of a network] so that it is not possible to connect to our computers from the outside, but we didn't do anything for email privacy. I was considering to use some package to encipher email messages, but the problem is that I don't know if any of our clients and/or partners use anything like that. If they don't it is useless. Furthermore, I don't think that anything that is really important is transmitted by email." Some said there were certain transactions that they would not carry out over the net because of security problems. Several mentioned financial transactions and using credit cards as something they would like to do, but were wary of. Some had security conscious clients, such as the ministry of defence, so the transfer of drawings was a problem. For more than half the firms we interviewed security was not an issue: "There has not been a problem. We're such a small firm that we don't have to worry about it-as well as the type of business we're in. There is nothing like patient confidentiality as in medicine to worry about." The question of security in the pre-computer office primarily pertained to security against fire, and was rarely concerned with the theft of drawings. In the CAD office it pertained to the corruption of data and file loss. For the CMC office, security extends to the issue of outright theft of data or the use of disk space by cunning hackers, or the inadvertent leakage of information as it is sent through the now pervious electronic boundaries of the practice. CMC discloses security as a new issue.

CMC primarily pertains to texts, whereas CAD is ostensibly about drawings. Most of the practitioners said CAD was still the primary reason for buying computers in the firm-asserting the priority of drawing in design practice. One practitioner said: "I say primarily for CAD, but only because CAD without communications is feasible, but for an architect communications without CAD is in my opinion not feasible (what are you communicating, if you can't communicate drawings?)" But some said that they would now purchase computers primarily for CMC: "I use computers primarily for word processing, spreadsheets, and communications. Starting anew, I would do the same."

The aim of this precise and secure commerce in texts, is to make better decisions, but it is also to gain access to other people, as a means to better decision making, but also as an end in itself.

Collaboration

Much has been made in the popular literature about the ability of CMC to foster community (Rheingold, 1993; Jones, 1995), and many see it as providing an opportunity to realise the Enlightenment notion of an informed and active citizenry-the re-institution of nineteenth century bourgeois cafe culture. From the inception of the Internet, the primary focus of CMC appears to be to put people in touch with one other. In this it differs markedly from other computer technologies such as CAD which is ostensibly concerned with one-way communication via the production of drawings and other contract documents.

Community inheres within practice. The concept of practice (or *praxis*) as advanced by philosophers of pragmatism, is of engaged action derived not from theory or rule (which pragmatists see as particular forms of practice), but from practices "taken over" from one's community (Dreyfus, 1990). The everyday concept of *professional* practice also implicates notions of community. Professional practice involves being admitted to a group through the processes of education, training, work experience, elaborate initiation procedures, and being a part of a group. Practitioners are professionals working to the norms of a professional community (Fish, 1989)-the associations with their registration procedures, legal requirements, and various other technologies or institutions of community. The communal nature of practice is often clouded over by the vision of the practitioner as the independent scientist, abetted by computers, CAD and other advanced technologies, and able to apply theories to reason independently and "objectively" about a design problem. The communal nature of practice is also partially obscured by the romantic conception of the designer as the lone creator of new ideas. Under both the objectivist and the romantic schema, design media, documentation, and now computer technologies serve as conduits, or conversely as impediments, to the transmission of ideas to reality. Under this conception, computers appear as a means of efficiently transporting the products of the designer's genius (design ideas) to builders, manufacturers and tradespeople, sometimes ignoring the complex interrelationship between the various groups involved in the building process. As with any communications technology, CMC promotes the conduit metaphor of professional expertise, but the two-way nature of CMC substantially ameliorates this tendency, and conspicuously directs attention towards the nature of professional practice as involving community. In doing so it discloses new ways of interacting with people.

Most of the practitioners we interviewed used CMC for remote collaborative work. Most said CMC was an extension or diversification rather than at the core of the practice's activity, but collaboration by CMC was central for some of the practitioners. For one practice, "collaborative specification sessions are the norm, and also collaborating in the field with my project managers using on-line Chat and Conference Rooms. Internally, using Lotus Notes, we set up a time to 'talk' and go through field condition problems. We expedite problems this way to streamline the project delivery process. We can post specifications, get pricing for materials etc. It is a very useful tool."

CMC is clearly implicated in changing conceptions of collaboration in practice. "I think of myself as a collaborative person, but CMC has made it easier, making me also more willing to help." According to another, "I think it [CMC] makes collaborations much more feasible. I do stuff that I would not have

considered practical before." Most said that CMC had affected the way they collaborate with others, it has increased the speed of working with consultants, it involves them with people they would not meet otherwise, and "it speeds up action and reaction time."

How do practitioners collaborate using CMC? Clearly CMC makes it possible to give and receive advice in ways that are more immediate and convenient than conventional means: "I think it will allow greater use of specialists. Suppose I have a really nasty stress analysis problem. I could send the model to some hotshot who could verify my results. It's not that convenient to do that right now. I think it will build a better infrastructure for engineers." CMC also instils new ways of collaboration taken over from metaphors of writing: "Danielle here in my office is working with Chris [in another office] on the production of a set of working drawings. Chris 'controls' the drawings. In other words, only he actually adds to the set. Danielle acts as critic, and conduit of client information, and my own critiques. To use a metaphor, Chris writes, and we edit." Another practitioner said: "Our first real exposure to the Internet was for collaboration. This is what convinced us to use it. Collaboration over the net was actually better than local collaboration because of the structured nature of the communication, the formal passing of the ball from person to person. The fact that when you passed the ball back, it had to be visibly different, or rather, if you'd done nothing, it was readily apparent. Also, just the formality of that 'passing' meant it was clear where the buck lay at any particular time. It was with the last person who received the project. So no excuses such as 'oh I thought that was you.' Also, there's something about the process that encourages each person to contribute just what he/she does best. I don't know exactly what it is. I think it's a product of these. In other words, the responsibility and accountability engendered by the formality of the communication leads one to concentrate on where your own contribution will be most noticed, and of best quality. And to pass off work you're not so good at, onto other members of the team." According to this practitioner, collaboration via CMC has an affect on the building product: "Buildings or structures are subtlety changed, in that Chris (for example) brings a different angle to architecture. So a different mix of people made possible by CMC leads to a slightly different product."

Collaboration is at the core of CMC discourse and practice, and firms that adopt CMC take over and adopt this discourse to their own uses. CMC brings issues of collaboration to the fore in ways not already apparent in practice. One aspect of this preoccupation with collaboration is its extension into the global sphere.

The global enterprise

The fourth phenomenon that CMC discloses to practice is the firm as a global enterprise, extending its boundaries beyond the local, and even the national arena (Deans and Jurison, 1996). One of the most exciting aspects of CMC use is the presumed internationalisation of practice, even small practice: "CMC allows one to be much more involved on a frequent basis in activities which may be at some distance away from ones physical and time based location-something close to telepresence." It seems that this trend is likely to continue: "It will further the trend of architects collaborating with other architects and consultants all over the country and the world." For one practitioner the collaborative aspects of CMC only really came to the fore in the international arena: "It has allowed me to collaborate with people I would not otherwise have met, people far away. Locally, it is a bit helpful but hasn't really changed the collaborative process much." The small firm is also now able to claim international status: "Consultants are now national and coast to coast. Clients are starting to wind up around the world. The notion of practice in your own backyard has been destroyed forever. A small firm like ours can now compete for international work and get the work, and do it better, cheaper and faster than a much larger firm." According to another small practice: "The consultant base has greatly expanded. We now employ two consultants, Chris in Scotland, and Jack in Los Angeles, whom we never would otherwise have considered if CMC were not available." Once the firm has begun operating at an international level then it becomes dependent on global communication. One practitioner provided a graphic example, which also demonstrated the international scope of the small practice's operations: "I am currently working on a joint funding proposal for a project in India, with Howard at the University of Oregon. The proposal and various bits and incarnations get passed back and forth. We also

just completed a paper for a conference in Tunis this way, and the whole process broke down, because I left the net (in Papua New Guinea) and had to contribute by fax, which Howard then could incorporate into the main text, etc. It was a good lesson on how dependent we have become on the net for this kind of collaborative passing back and forth."

Many of the practitioners reported that there were now tasks they could accomplish with CMC that they could not accomplish otherwise, and most of these tasks pertained to practice in the global arena. Practitioners did not need to move around as much, had a larger customer base, can possibly advertise the existence of firm and its services, they can discuss problems and issues with other professionals not in direct competition, the idea of working with satellite offices is less formidable than before, they can draw on a broader talent base, and they need never lose people just because they leave the country. According to one practitioner, with CMC you can do "everything from getting contract documents out in half the time to communicating to the world and getting information accurately, and quickly." CMC means you can get access to people anywhere to work on a project, at least in the future: "A virtual office would have the flexibility to select team members and personnel based on factors other than location. I see that it is conceivable for a design team to use talent from all over the world to build and design buildings, and then either disband or reconfigure to adjust to the next job. I feel that more opportunities in the architectural field can open up this way." Apparently CMC also makes communication easier across national boundaries for people who have difficulties with foreign languages. One person for whom English was not their first language reported: "It also helps us because it is easier to write in English than it is to speak it. I can't think to get interviewed by you by voice."

Many of those we interviewed used CMC while travelling: "I have used this often by emailing/Chat/ Conference room communications whenever I'm on the road (3 times a month now). Just dial in and you are virtually in the office. I can use either Lotus Notes or a direct dial into my computer through LapLink for Windows, and its as if I'm there." According to another practitioner: "I use it to stay in touch with the office with email. I'll subscribe to Delphi and use their packet switching network which allows local dial-up connectivity in most major cities, then gateway my messages from the field into the Internet to be delivered here at the office." As a transnational project, our interview procedure proved disclosive for some. One practitioner said: "The fact that I am communicating with you at this moment, tells me a lot. I never imagined before using CMC what could be happening at the other side of the world, in an area of my interest."

Poor quality telecommunications are an impediment to globalisation in some countries: "In Europe, I used Eunet to Telnet back to my home account. In Papua New Guinea, there is no local access, and I find the international lines too noisy to dial into Sydney with a terminal emulation program." Apparently, good communications links are vital for the international practice. Most practitioners said that if their firm relocated then CMC would make little difference to where they relocated. Most said it is important to have a good phone connection or low cost access point. Long distant phone calls were considered undesirable. Some said it is necessary to be close to the client base and that is the major consideration. A few implied that CMC gave them more freedom to locate, that with CMC they could move out into the suburbs, the countryside or somewhere more physically isolated. Relocation had to take account of CMC "only if there were no ISDN service planned for the location. Otherwise, it doesn't matter where you are any more. You can practice anywhere on earth and get architecture built." The practitioners did not yet see the Internet as sufficiently ubiquitous to allow unshackled movement: "I don't think we can have the Internet everywhere. Obviously we can't go too distant from our clients, but in Italy the most profitable area for a company like mine is the north, and we can get an Internet connection everywhere in the north of Italy. So there are no problems. I don't think we will move to the south." One practitioner suggested that CMC made it more feasible to relocate to a cheaper cost centre: "When we have better communications it should be possible for one office to handle the 'sales' side of the business with another office (with lower overheads) doing the 'donkey work.' For example, office rentals and salary costs in London are dearer than Yorkshire, so why not do the bulk of the work from a cheaper cost centre?"

There are certain tasks that are difficult to accomplish on the international arena, even with CMC. One

practitioner felt that it was essential that you already know the people you are dealing with "face to face," and had never recruited anyone on the net: "We knew both these people [we worked with] beforehand. This is important. We've never recruited anyone via CMC. I am aware, from reading Tom Peters latest book, for instance, plus the newspapers, that some firms are recruiting over the net as well." Professional registration is a further impediment to the globalisation of practice: "Architects and engineers are licensed by state and province, not nationally. There is not always reciprocity between jurisdictions. The process of getting licensed is time consuming. If I got a job in New York or Washington state I could get licensed there, however I cannot get licensed in California, so would have to collaborate with a local architect, and as I would not be the architect of record, would be limited severely in what services I could perform." One practitioner sought to extend his professional registration as a consequence of CMC: "I am discussing doing collaborative work with two people I have met over the net. As a result I am getting registered in the US as well as in Canada."

Several practitioners also reported that CMC had influenced the spatial distribution of their client and consultant base, but some thought that "the fax machine was the most significant technology in that regard," or simply that CMC "makes it easier to keep in touch with them, as now we can send programs by ftp, whereas previously we had to send floppy disks or tapes." One practitioner observed that "people still want to see you before they buy services." One thought that CMC "provides a greater presence at client locations-more constant servicing of the client's needs. Its great for that added touch."

CMC also offers the prospect of working intimately with other designers through real-time video linkages, of the kind explored by various researchers (Minneman, 1991; Scrivener, 1993), though none of the practitioners had yet done so: "People are already talking about interactive design sessions via CMC. I suppose that means no actual meetings except those connected by wire. The intuitive relationships between parties can suffer or be dissipated. But the market possibilities are huge." The intimacy of work connections will extend to working with consultants according to another practitioner: "CMC technology will enable real-time interactive design with design engineering occurring in real time simultaneously with load calculations as well as hazard mitigation options. You will see artificial intelligence wedded to these appliance-like design/ modelling tools where clients and providers will work together and collaboratively build the data superhighways. Increasing bandwidth will enable these to occur in the more industrialised nations first then gradually out to the rest of the world as the highways are extended. (My speciality is hazard mitigation.)"

Sociologists such as Giddens (1990) have observed that globalisation paradoxically carries with it a trend towards local concerns. The global and the domestic, even the personal, becoming intertwined. An obvious and literal manifestation of this phenomenon is that most of the interviewees worked from home using CMC, some spending as much as two to twelve hours per week. For some of the interviewees their office was their home. With CMC, the domestic sphere becomes intimately connected with the global. As well as bringing the world of business into the home, the play between the local and the global may have ramifications for the kind of architecture we see: "There will be more sameness of design in terms of regionalism on the one hand, and much more mixing, more postmodern play, on the other. Both would be responses to the increase in communication-an intensification we have already seen from at least the seventies on." According to one practitioner new ways of working will emerge to accommodate the play between the local and the global: "Field services will change drastically. They are the one aspect of architectural practice which cannot be fully automated. As we work elsewhere, field services will increasingly become a specialty of some firms, as will regulatory consulting, ie firms expert in local conditions and regulations. Local architects for field services working with remote architects will become increasingly prevalent. This represents a major shift in project delivery. Traditionally, field services and design services are provided by a single firm. There will be a shift in how we relate to our peers, as there will be much more collaboration and cooperation rather than just local competition between architects."

The prospect of globalised practice has structural ramifications that are already in place for the professions: "If architects catch up in the computer literacy stakes, then I expect that you will see (as perhaps you do in other industries today) a mix of many small, mobile, specialist companies coupled with a few big companies

characterised by not so much big staffs as big reputations, capital bases, and computing resources, all getting together into temporary alliances to do specific projects." Another practitioner also drew attention to new modes of practice that are emerging: "I read a piece just today, that Chiat/Day is planning to get rid of its offices. Small teams assembled for particular projects will rent hotel rooms, using mobiles and laptops, then dissolve and reassemble differently for other projects. I need to read up on 'hotelling.'"

This restructuring of the nature of firms and their relationships has been evident for some time (Cuff, 1991; Duffy, 1992), even prior to the incursion of CMC and the Internet. It seems that CMC enables firms of any size to participate in this restructuring rather than wait to be swept along by its tide.

Needs and disclosures

CMC brings certain changes in practice into sharp relief, particularly, as we have seen, in the case of the entrepreneur, a heightened orientation towards texts, a sense that one is always working with others, and a sense of being part of a global network. Our interview process also afforded an interesting illustration of technological disclosure at work. The technology informed the interview process, as the object that was the focus of the study was also the vehicle of communication, and the proof of the applicability of the technology. The questioning and the responses were highly reflexive. In addition, the interview was an exercise in textual manipulation involving the exchange of strings of characters and assertions. Typically, an interview would last for two or more hours, and was tiring for both parties. Much less can be typed than can be spoken in the equivalent time. The interviewer had each question pre-stored ready for release as the previous question was dealt with. There were frequent interruptions to the conversation from outside. There were annoying time delays and disruptions to communication in some cases as contact would be broken through the idiosyncrasies of the Internet and local gateways. It would have been possible to deal with the interview asynchronously, by emailing a questionnaire to the practitioners, but the approach we adopted had several benefits. Real-time conversations in text was an aspect of CMC that most of the recipients had not tried before and so could feature in their reflections. It also afforded the usual benefits of an interview over a questionnaire, in that the interviewer was able to seek clarification during the interview, and could stimulate further responses. Taking on board notions of control and efficiency promoted through text-based CMC use, we could say that an advantage is the efficiency and accuracy of the interview process. Unlike taking notes or transcribing tapes, every word is recorded and already in an editable form. Knowing that there was someone on line attending to one's every word also added an edge to the interviewee's comments, and there was a complete response rate, though some of the interviews were not completed due to technical problems.

The consensus of those we interviewed is that the state of CMC technology as it is at the moment is a foretaste of something more significant around the corner. For one, the future lies with greater connectivity and greater bandwidth for more sophisticated collaborative activities: "I expect that my mobile computer will be constantly hooked to a wide area network. I expect full motion video links over the net (videotelephony). I expect real-time collaborative authoring of text and graphical documents. I expect super easy interfaces, so that it's a matter of pick-up and play, for new staff. I expect to be working more from my living room, with meetings in cafes. I expect my clients to be slightly more computer literate, but don't hope for much there, and I expect to use CMC more for client presentations, bringing remote workers in on meetings." It will be commonplace for people to collaborate at a distance using any item of software: "All programs will have CMC features in them. Now all programs are networked. In the future they will be multiuser." Another saw CMC providing 'intelligent' access to interactive 'virtual reality' images through VRML (virtual reality modelling language): "I can see 'intelligent agents' searching VRML based Web Sites across the globe, searching for 3D images of products that I am specifying on my next architectural project." Another practitioner saw the future in terms of miniaturisation and ubiquity: "I hope all communications will be in small hand held intuitive devices. I want inexpensive and immediate data and voice links from anywhere-cars, home, you name it-and I want access to computer data anytime." For another practitioner, the future also augurs the possibility of designing the virtual, without ever expecting it to become real: "The more you show, the more responsible you are for turning an image to reality. On the other hand, we will be able to make these images to stand by themselves, to create virtual spaces that will never even make the attempt to

become real. This frightens me a little." Some see a future of major structural changes to professional life: "I expect to make more and more use of 'mother ship' companies-bigger companies with big computing resources, that I can call on for backup for bigger jobs." One practitioner wistfully remarked: "I don't see architectural practice existing the way it practices today-it will cease to exist due to technology passing by a sleeping profession. But the few that see this trend will keep this noble profession alive."

If these changes come to pass it will not be because anyone "needed" these technological developments, or because there is a pressing need for changes to the professions. There is an inevitability about technology. Some philosophers say we get caught up in technologies because we are inescapably technological beings (Heidegger, 1977; Borgman, 1984). To understand how a technology is taken up by practice we should approach the issue of needs with caution. We began by introducing the concept of disclosure. *Disclosure* is a philosophical term used by phenomenalists to describe the process whereby something is both revealed, but also changed through that process (Heidegger, 1971). A common example used is that of a work of art. A painting of a tree can be disclosive in that it reveals something, possibly something new, about what a tree is. The painting also changes the way we look at trees, define them, and even how we treat them, but the painting does not communicate first, and then disclose. We bring as much to the painting as the painting presents to us, as does the context in which the painting is created and displayed, the painting's history, and the whole of culture. The notion of disclosure does not foreclose on realist or idealist notions of what a painting is, or which is the subject and which the object. It starts with the whole, with context, community and practice. According to this theory, an item of technology such as a bridge is also disclosive in that it reveals the nature of the river that it crosses. It also clearly influences the patterns of movement of the communities and systems of which the bridge forms a part. To say that the bridge discloses does not foreclose on the matter of agency-whether it is the bridge that causes the change or the circumstances of its building, or the planners, engineers or builders who decided on its configuration, or the users of the bridge. To talk of disclosure does not invalidate talk of causes, but who or what is the agency of change is a matter for interpretation, which is built on the fact that the bridge primarily discloses. To say that a bridge discloses is not to introduce another form of causality, or a new interpretive foundation for understanding technologies. Disclosure is an indeterminate notion. The advantage of using it is that the term itself discloses new ways of looking at the role of technology-at least, it privileges the issue of practice, context, community and the nature of discourses about technology.

In the case of computer technology we can see that its introduction into a firm both discloses aspects of the firm's operations that were perhaps not regarded as important before, it serves to redefine the firm, and it is implicated in the actions of the firm. The notion of disclosure does not even presume that these aspects of the firm pre-exist. To say that the introduction of CAD discloses firms as custodians of databases (Coyne et al, 1996) suggests that firms always had data in the form of drawings, and the new technology made that function more obvious. But we could equally say that the concept of drawings as data, as we currently understand the term, did not really exist before the invention of the computer.

The rhetoric of needs presupposes that the firm has a particular pre-given character, that it is able to identify shortcomings in its operations, that it is sufficiently in control to develop plans to meet those needs. The rhetoric of needs draws our attention to goals, methods, and plans, optimality, and good practice. This is a privileged discourse in today's corporate world. It provides a certain sense of security. On the other hand, the rhetoric of disclosure draws our attention to other issues marginalised by the rhetoric of needs, such as the overall character of the matrix into which technologies are introduced and how they are changing. It draws attention to the paradigm, the culture, the problem setting, the field of metaphors, and practice. The issues of needs is presupposed by the matter of disclosure.

As communication features in our investigation of CMC in practice, it is worth reflecting on the nature of communication as disclosure. We can consider the conventional example of working drawings. The needs oriented way of looking at working drawings is to say that they serve as a means of communicating intentions from the designer to the contractor. This is a valid construct, but, according to the disclosive view, it is presupposed by the more basic phenomenon of the nature of working drawings to disclose (Coyne, 1994).

The drawings do not just disclose the designers wishes to the contractor, but they reveal something about the builder's and the designer's practices. Making, interpreting, checking, and working with contract documents are practices. Designers engage in the practices of designing, and builders engage in the practice of building. Through training, experience, and engagement with their various professional communities, these practices are built into their roles as professionals. Builders do not require instructions in order to build. The builder is already caught up in particular ways of doing things when left to his or her own devices. Contract documents are interventions into that practice. Several things happen when the builder interprets these drawings. Every interpretation involves coming to a text, or drawing in this case, with certain expectations. Interpretation involves an indeterminate and cyclical play of expectation and revision. In the process, the drawings disclose aspects of the builder's practice, what is different about the builder's construction practice. Whereas the builder would extend the roof to form an eaves, the drawings indicate something different-the continuation of the wall above the eaves line to form a parapet. The drawings both reveal and also, hopefully, are implicated in the builder's action, though it is not simply the drawings that accomplish this but the various practices that the builder, the trades, the designer and the drawings are caught up in.

According to this view, CAD models of buildings appear in a particular light. As long as we see CAD models as primarily meeting communication needs then we tend to focus on the accurate transfer of information-an elusive quest. The view of CAD models as disclosive directs our attention to the changing practices in which those models operate, including the new emerging practices of managing CAD databases. The same applies to CMC technologies. They are disclosive in the sense that they reveal what someone else at the other end of a communication channel wants us to know, but more importantly, they reveal aspects of our changing practices.

CAD has been around for so long that there is an accepted rhetoric of need. Everyone else has CAD so we need it as well. CAD is an efficient way to handle drawings, though these assumptions have been challenged by many researchers. CMC is an interesting area of study from the point of view of disclosure as there are as yet no well established practices that embrace it. Neither have practitioners constructed a sophisticated rhetoric of needs through which to justify its introduction. CMC is still alien, and as such it has greater power to disclose the nature of current practice. We have described the way CMC discloses the firm as an entrepreneurial enterprise, a handler of texts, a collaborator, and a player in the global arena. What we see ultimately is how CMC discloses the fragility of current modes of practice.

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References

Austin, J. (1966). *How to do Things with Words*, Harvard University Press, New York.

Borgman, A. (1984). *Technology and the Character of Contemporary Life: A Philosophical Inquiry*, University of Chicago Press, Chicago, Illinois.

Coyne, R.D. (1994). Heidegger and virtual reality: The implications of Heidegger's thinking for computer representations, *Leonardo*, Vol.27, No.1, pp.65-73.

Coyne, R.D. (1995). *Designing Information Technology in the Psotmodern Age: From Method to Metaphor*, MIT Press, Cambridge, Massachusetts.

Coyne, R.D. (1996). Language, space and information, *Intelligent Environments*, ed. P. Droege, Elsevier Science, Amsterdam, The Netherlands, pp.503-528.

Coyne, R.D., McLaughlin, S., Newton, S. and Jumani, A. (1996). Computers and change: How is design practice coping? *Environment and Planning B: Planning and Design*, to appear.

Cuff, D. (1991) *Architecture: The Story of Practice*, MIT Press, Cambridge, Massachusetts.

Deans, C. and Jurison, J. (eds) (1996). *Information Technology in a Global Business Environment: Readings and Cases*, Boyd and Fraser, Danvers, MA.

Dennis, A. R. and Valacich, J. S. (1993). Computer brainstorms: More heads are better than one, *Journal of Applied Psychology*, 78(4), 531-537.

Derrida, J. (1988). *Limited Inc*, trans. Samuel Weber, ed. G. Graff, Northwestern University Press, Evanston, Illinois.

Dreyfus, H.L. (1990). *Being-in-the-World: A Commentary on Heidegger's Being and Time Divison I*, MIT Press, Cambridge, Massachusetts.

Duffy, F. (1992). *The Changing Workplace*, Phaidon, London.

Fish, S. (1989). *Doing What Comes Naturally: Change, Rhetoric and the Practice of Theory in Literary and Legal Studies*, Duke University Press, Durham, Southern Carolina.

Fulk, J. (1993). Social construction of communication technology, *The Academy of Management Journal*, 36(5), 921-950.

Garfinkel, Harold (1967). *Studies in Ethnomethodology*, Polity Press, Cambridge.

Giddens, A. (1990). *The Consequences of Modernity*, Polity Press, Cambridge.

Heidegger, Martin (1971). The origin of the work of art, in M. Heidegger, *Poetry, Language, Thought*, trans. A. Hofstadter, Harper and Rowe, New York, pp.15-87.

Heidegger, Martin (1977) *The Question Concerning Technology and Other Essays*, Trans. W. Lovitt, Harper and Row, New York.

Hill, G. W. (1982). Group versus individual performance: Are N+1 heads better than one? *Psychological Bulletin,* 91(3), 517-539.

Hiltz, S. R. and Johnson, K. (1989). Experiments in group decision making, 3: Disinhibition, deindividuation, and group process in pen name and real name computer conferences, *Decision Support Systems,* 5, 217-32.

Hiltz, Starr Roxanne and Turoff, Murray (1993). *The Network Nation: Human Communication Via Computer,* MIT Press, Cambridge, Massachusetts.

Jones, S. G. (1995). Understanding community in the information age, *in* S. G. Jones (ed.), *Cybersociety: Computer-mediated communication and community*, Sage, Thousand Oaks, CA, pp. 10-35.

Lakoff, George (1987). *Women, Fire, and Dangerous Things: What Categories Reveal about the Mind*, University of Chicago Press, Chicago.

Matheson, K. and Zanna, M. (1989). Impact of computer-mediated communication on self awareness, *Computers in Human Behavior*, 4, 221-233.

Matheson, K. and Zanna, M. P. (1990). Computer-mediated communications: The focus is on me, *Social Science Computer Review,* 8(1), 1-12.

McGuire, T. W., Kiesler, S. and Siegel, J. (1987). Group and computer-mediated discussion effects in risk decision making, *Journal of Personality and Social Psychology*, 52(5), 917-30.

McLuhan, M. (1962). *The Gutenberg Galaxy: The Making of Typographic Man,* University of Toronto Press, Toronto.

Minneman, S.L. (1991). The social construction of a technical reality: empirical studies of group engineering design practice, *Report SSL-91-22* [*P91-00160*], Xerox, Palo Alto Research Centre, Palo Alto, California.

Rice, R. E. and Associates (eds) (1984). *The New Media: Communication, Research, and Technology*, Sage, Beverly Hills, CA, pp. 129-156.

Rheingold, Howard (1993). *The Virtual Community: Homesteading on the Electronic Frontier,* Addison Wesely, Reading, Massachusetts.

Schmitz, J. A. and Fulk, J. (1991). Organizational colleagues, information richness, and electronic mail: A test of the social influence model of technology use. *Communication Research,* 18, 487-523.

Scrivener, S.A.R., Harris, D., Clark, S.M., Rockoff, T. and Smyth, M. (1993). Design at a distance via real-time designer-to-designer interaction, *Design Studies*, Vol.14., No.3, pp.261-282.

Short, J., Williams, E., and Christie, B. (1976) *The Social Psychology of Telecommunications.* London: Wiley.

Sproull, L. and Kiesler, S. (1991). *Connections: New Ways of Working in the Networked Organization,* Cambridge, Mass: MIT Press.

Steinfield, C. W. (1986). Computer mediated communication in an organizational setting: Explaining task related and socioemotional uses, *in* M. L. McLaughlin (ed.), *Communication Yearbook 9*, Sage, Newbury Park, CA, pp. 777-804. .

Trevino, L. K., Daft, R. L. and Lengel, R. H. (1990). Understanding manager's media choices: A symbolic interactionist perspective, *in* J. Fulk and C. Steinfield (eds), *Organizations and Communication Technology,* Sage, Newbury Park, CA, pp. 71-94.

Valacich, J. S., Paranka, D., George, J. F. and Nunamaker, J. F. (1993). Communication concurrency and the new media, *Communication Research*, 20(2), 249-276.

Valacich, J. S., Dennis, A. R. and Connolly, T. (1994). Idea generation in computer-based groups: A new ending to an old story, *Organizational Behavior and Human Decision Processes,* 57, 448-467.

Walther, J. B. (1992). Interpersonal effects in computer-mediated interaction: A relational perspective, *Communication Research,* 19, 52-90.