Social impacts of computer-aided architectural design

Thomas W Maver

ABACUS, Department of Architecture and Building Science, University of Strathclyde, Glasgow G1 1XQ, UK

In 1985 the Commission of the European Communities, as part of its concern for social adjustment to technological change, invited the eCAADe (an association of European Schools of Architecture set up to promote the effective adoption of CAAD in architectural education) to prepare a report on the social impacts of CAAD. This paper summarises the report and deals primarily with impacts on the practice of architecture, on architectural education, and on the architect's relationship with other members of the design team and with the client and users of the building. Recommendations are made for initiatives in education, research and development.

Keywords: architectural practice, clients and users, computer-aided design, education and training, research and development

BACKGROUND

eCAADe

The eCAADe (Education in Computer-Aided Architectural Design in Europe) is an association of European Schools of Architecture committed to collaboration in the effective introduction of computer-aided architectural design (CAAD); its statutes are registered in Brussels.

With modest financial support in the form of CEC Grants for Higher Education—administered through the Office for Co-operation in Education—the eCAADe has been able to engage in a number of activities to promote its objectives:

- Conferences—four international conferences have been organised (Delft 82, Brussels 83, Helsinki 84 and Rotterdam 85); the fifth international conference will be held at the University of Rome in September 1986.
- Directory—a directory of CAAD activities and facilities within the European Schools of Architecture has been compiled and is regularly updated.
- Didactica—a set of lecture material has been compiled and translated into English, Dutch, French and Italian. A set of audio-visual aids for teaching is in preparation.

CEC initiatives in information technology

The importance of information technology (IT) on European industries has been long recognized by the Commission. Early initiatives, such as the ESPRIT programme, were concerned to stimulate collaborative development of the new technologies; more recently interest has grown in the social implications of these developments.

In January 1984 a communication entitled *Technological Change and Social Adjustment* went to the Council. Its purpose was:

0142–694X/86/04178–07 $03.00

. . . to propose a Community strategy for new technologies which, complementing those already launched in the sphere of industry, research, development and innovation, will bring a positive response to the social challenges.

The need for joint action was elaborated under three priority headings:

- education and training
- organisation of working and living conditions
- participation in technological change

Within the first of these three fields of action the communication recognized the Commission's ability to:

. . . support Community level initiatives to introduce new Information Technology into education, teacher training, the development of software and hardware systems, and the exchange of experimental data.

eCAADe proposals to the CEC

The social impact of the advances in IT, and in particular in CAAD, was already a concern of the eCAADe. Much of the collaboration with the eCAADe had focused on the innovative development and experimental use of computer software that explains the principles underlying a new generation of design aids and provides an insight—to students, teachers and practitioners alike—into the 'cause and effect' within the design decision-making activity. From this pilot work it was already clear that advances in CAAD would not only affect the quality of the built environment but would fundamentally change the nature of architectural practice, the relationship between the architect and the client/user and, of course, the whole educational process at undergraduate, post-graduate and mid-career levels.

CONTEXT

Related investigations

Serious consideration has been given to the possible impacts of computer technology on society for the past decade. Of particular relevance are the writings of Weizenbaum[1,2] and Rosenbrock[3–5]. The topic of 'Human Choice and Computers' has been the focus of attention of a Working Party set up as early as 1974[6] by the International Federation of Information Processing (IFIP). At its most recent meeting this year in Stockholm[7] the IFIP Working Party structured its discussions around:

- the working environment
- the bureaucratic environment
- education and training
- social and private life
- awareness

Amongst the conclusions arising from the discussions were that awareness needs to be strongly promoted and that research and development has to be undertaken in a more holistic manner to include social as well as technical issues. In these respects the social scientists within the Working Party were more pessimistic than were the technologists.

In the specific realm of computer-aided design (CAD), the views of M J Cooley are of particular relevance. Cooley's writings[8–11] warn that information technology could bring about the same de-skilling of the designer as automation brought to the craftsman; his contribution to the debate on the promises and threats of CAD was featured in a special session of the CAD76 Conference in London[12,13].

Building industry

While there is clearly a close correspondence between CAD generally and CAAD specifically, the differences—in terms of the process and the product of building design—could prove to be significant in the formulation of strategies to accommodate social adjustments to the changing technology.

The scale of the building industry has to be appreciated. It is, in fact, Europe's second largest industry accounting for around 12% of the gross domestic product in member state countries and employing 8% of the working population (i.e. one in 10 of all males in employment). Despite its scale, it must be seen as 'under-developed': fragmented, unsophisticated, unprogressive. The eventual impact of IT is thus likely to be major.

The product

- With very few exceptions, each building is more or less 'one-off'; there is no prototype and production run.
- In comparison with other designed artefacts the building has an extended life-span—nominally 60 years; over such a life-span there is likely to be considerable change of use.
- As a consequence of the extended life-span, the ratio of existing stock to new products is increasing; an increasing proportion of design effort is thus associated with rehabilitation and conservation.
- Over the life-span of the building, the life-cycle costs may aggregate to as much as 10 times the initial cost; a significant element of the recurring cost is due to energy consumption.
- Buildings are location specific and topographically complex; they play a very direct role in our everyday life and they are, perhaps more than any other designed artefact, culturally significant.

ARCHITECTURAL PRACTICE

Current situation

Studies of architectural practices have shown the proportions of time spent in a typical practice to be:

feasibility and scheme design	26%
working drawings	18%
office and contract administration	31%
site supervision	10%
research and other	15%

The uptake of CAD clearly will alter this distribution of time and effort. Current uptake in architectural practice can be considered under the broad headings of management, drafting and design.

Management

Computer programs for a wide range of office management and information handling are available. These include:

- word processing
- payroll operation
- critical path analysis
- project evaluation and report techniques
- specification writing
- regulation checking
- facilities planning
- bills of quantities

Currently, these packages tend to exist as discrete entities implemented on different machines; the management suites now being offered on the more powerful personal computers (PCs) represent the kind of integration, ease of access and flexibility of reporting which is surely possible.

Drafting

The turnover in computer-aided drafting systems worldwide is 4000M ecu; of this, perhaps 12% of the systems are used in the context of building design. Originally based on mainframes and selling for around 150 000 ecu, there has been a move down to networked 32-bit workstations selling at around 40 000 ecu per station; at the same time there has been a rapid growth in the number of PC-based drafting systems available at around 20 000 ecu complete. Most, if not all, of the systems offered handle two-dimensional (plan) representation of the building with possible extrusion of the plan into the third (or 2.5) dimension.

Design

Predicting the cost and performance consequences of alternative design decisions requires a full three-dimensional model of the building in which the topographic relationships are explicit. Development of applications software for design decision making has largely been piecemeal and has focused on specific computation-bound issues such as energy consumption and structural analysis; the uptake of such programs by architectural practice has been minimal, with Europe trailing the USA.

Relevant issues

The problems and prospects concerning the adoption of CAAD in architectural practice can be considered under three broad headings—profit motivation, professional responsibility and integrated design.

Profit motivation

Architectural practice has been much quicker to adopt software for management and drafting than for design. The most obvious reason has to do with profitability: whereas management and drafting programs may allow the practice to carry out necessary functions more quickly or with fewer people, the use of design programs may cause time and effort to be spent on areas of decision-making which currently do not receive explicit attention. Worse, the application of design programs may result in more economical design solutions with the consequence that the fee to the practice—still proportional in most European countries to the capital cost of the building—will be reduced. This situation can be seen to be changing: clients, increasingly conscious of life-cycle costs, are demanding evidence of more cost-effective solutions; at the same time there are moves by the professional institutions to abandon the fixed fee structures.

Professional responsibility

Architectural practice is hedged round with regulations; professional responsibility weighs heavily on a practice and escalating indemnity premiums are a major cause for concern. Design software raises new questions of responsibility. Should the practice stick to the existing (and possibly crude) guidelines or pursue a more appropriate solution using innovative and possibly unvalidated design software? As programs are validated and reliable results generated, existing guidelines and regulations will require to be re-written. Some will take on a wholly new form placing responsibility on the architect to evidence, by the use of approved design programs, the achievement of a safe or efficient design solution.

Integrated design

A unique grouping of firms comes together to design and construct a building. The probability is thus low that all firms will have the same drafting system and this makes co-ordinated design effort extremely difficult. Efforts are being made to establish and use standards (e.g. IGES) which will allow different two-dimensional drafting systems to communicate. Other engineering industries are making significant use of these standards but in building design the standards are largely untried. There is a clear need for a sustained research and development effort to specify the structure of a computer-based building description which would support management drafting and design applications in a truly integrated manner.

Possible impacts

Within architectural practice

The effect of CAAD on the employment of architects will be negligible in comparison with the response of the building industry itself to economic growth or recession. On balance it is thought that job opportunities will increase: staff savings through the efficiencies of computer-aided drafting will be more than offset by the profession's ability to offer a more comprehensive service—extending into facilities planning, building management and redesign, etc. There is the danger of de-skilling, particularly of those architects currently considered to be expert in technical matters and of those architects and technicians who have particular drafting skills; re-skilling will take place informally (though sometimes traumatically) within the office and more formally in Schools of Architecture. The number of very large and very small private architectural practices will grow at the expense of medium-sized practices and the public sector will expand with corresponding shrinkage in the private sector.

Within the design team

As more integrated CAAD systems become available there is certain to be a closer understanding generated between the various members of the design team and a blurring of their sectarian interests. There is scope for the architect, should it seem appropriate, to regain the means of communication and control, conceptually and contractually.

Within the building industry

Whereas an increasing proportion of design work in Europe will focus on the conservation and rehabilitation of existing building stock, the same is not true in the Middle East and in the Far East. If European building firms are to compete and win contracts in, for example, China, consortia of firms subscribing to integrated computer-based systems will have to be formed.

EDUCATION AND TRAINING

It is important to make a distinction between training and education. There is a major requirement to set up courses for the training (and re-training) of architectural technicians in the effective operation and maintenance of CAAD systems and this topic will essentially displace the current training in draftsmanship. There will also be an element of training required in the undergraduate and postgraduate courses for architects but it is substantively more important to establish the *educational* issues which underlie advances in CAAD.

Undergraduate courses

Three levels of education and training of architectural undergraduates can be identified:

- training students to use existing CAAD systems and educating them critically to evaluate and select between them; this will involve consideration not only of the technical merits but of the management and economic factors involved. A teaching input from practice is seen as vital to this level of course
- using CAAD systems within Schools of Architecture as a mechanism for *design* education. The emerging integrated design programs allow students to explore, over a wide range of competitive solutions, the causal relationships between design decisions and the resulting cost and performance consequences. There is cause for optimism that the approach to design education will reinforce the importance of a systemic (and integrated) view of architectural design based on a fully three-dimensional model of the building.
- Specialization in the design of design tools. There is scope for allowing some students (perhaps only in some Schools) to specify, develop and even implement prototypical computer-based design tools. It is not suggested that the outcome of their endeavours will be of direct use (any more than it would be suggested that we build the buildings which students design!). The purpose is to encourage an explicit formulation of the design decision-making activity and to appreciate the complexity of the building model. The more able students, especially if encouraged to work on the modification of or extension to existing programs, may make a significant contribution to system development.

The determination to keep architectural undergraduate courses 'general' and project based has led to great congestion in the curriculum. Room *can* be found for CAAD applications by making savings on the time currently devoted to manual methods for computation, report writing and drawing, and by more effective use of case studies.

Given the opportunity which CAAD systems provide for interdisciplinary design team working, the time is ripe for a more radical review of the overlapping educational requirements of architects, structural engineers, environmental engineers and quantity surveyors.

Postgraduate and mid-career courses

The concept of continuing professional development (CPD) is of the greatest importance especially in the rapidly advancing field of CAAD; opportunities will have to be provided for practitioners and teachers to be brought up to date.

The need is to develop a series of CPD modules hosted by selected Schools of Architecture but enjoying a significant teaching input from experienced architectural practitioners, software houses and hardware suppliers. CPD credits would be given and could be aggregated for the award of a Diploma or Masters degree. The teaching should be through case studies and design project work.

Resources

The most important resource is people and the most urgent task is to teach the teachers. Summer Schools lasting one week for teachers in Schools of Architecture have been piloted[14] and could be implemented, if resources were available, in each member state. There would also be significant advantage in Schools sharing scarce expertise through part-time or joint appointments. The problem experienced by all departments teaching in the field of IT is that of able and experienced teachers being lured away by practice; to ameliorate this problem, joint appointments between Schools and practices are suggested, as are secondments in both directions.

There is also a need jointly to develop and produce high quality teaching material—up-datable lecture material, case studies, project briefs, audio-visual aids and, above all, applications software. A great deal of material has already been produced and piloted (through eCAADe) but a substantial effort is required to package it in a way which is appropriate to the needs of all member states.

A number of actions could be initiated under the proposed Community Programme in Education and Training for Technology (COMETT)[15]:

- placement of architectural students and staff in practices already advanced in the use of CAAD
- secondment of architectural practitioners to Schools of Architecture already engaged in advanced study of CAAD
- collaboration amongst schools and practices on the design, development and testing of teaching material, particularly that appropriate to distance learning
- placement of new graduates and mid-career practitioners in advanced study courses: full time and part time
- extensions of the eCAADe data base of activities and facilities to include architectural practice
- sponsorship of round-tables between academics and practitioners to strengthen collaboration

CLIENTS AND USERS

There can be no denying the increasing dissatisfaction of the public in Europe with the performance of the architectural profession. It is appropriate then to consider what benefits, if any, will accrue to clients and to the users of buildings from CAAD.

Client-oriented CAAD systems

Clients may have to live with the economic, physical and social consequences of building design decisions for 60 years or more. Over that period, as already noted, the building and its facilities have to be managed and modified in line with changing needs. Clearly, if a computer-based model of the building was created during the design stage it is sensible to maintain and operate on that model over the life-span of the building itself. Access to the model will thus be needed by the client body and it follows that they should be involved in its establishment during the design phase.

Access to CAAD systems by clients with a large building stock will encourage the appraisal of that stock and the commissioning of design interventions by architects. Moreover, as the cost/performance attributes of increasing numbers of buildings are appraised, there will emerge—for the first time in the building industry—performance specifications to which client bodies (and eventually statutory bodies) will demand compliance.

The benefits to client bodies of CAAD is thus substantial and it is likely that the stimulus for the uptake of CAAD systems will come predominantly from large clients rather than from architectural practice itself. It is important, therefore, to think in terms of developing 'client-oriented' CAAD systems.

User participation in design

CAAD systems hold out the hope of a more explicit understanding of the cost and performance consequences of competing design solutions. Although the information base for design decision-making is thus greatly improved, the decisions themselves will still be a matter of subjective value judgement on what balance across the range of cost/performance variables is appropriate. It is argued by some that this judgement is best taken by those who will be most affected by the design decisions i.e. the building users.

This notion has been explored in two major conferences[16,17] and in a number of real-world experiments, mostly concerned with housing. The conviction is growing that computer-aided user participation in design has enormous potential in improving public satisfaction with the built environment. For this reason it is important that CAAD systems provide appropriate interfaces for non-professional users and are readily and cheaply accessible by the public. A model for this interaction can be found in the 'call for offer' system pioneered in France and Belgium, in which a consortium of designers and contractors respond to a performance profile established by architects working with users.

RESEARCH AND DEVELOPMENT

When viewed in relation to the level of funding for research and development in the major European industries, the investment in building R&D is an order of magnitude lower. A number of reasons can be advanced for this, the most cogent being the absence of an appropriate theoretical framework within which complementary R&D initiatives could be located. It is suggested that the computer-based modelling of the form and function of buildings, for the first time, provides such a framework. It follows that CAAD should become not only the *subject* of research and development but more importantly the *mechanism* for conducting research into the complex nature of design itself.

Substantial research and development effort is required in a number of key areas.

Design paradigms

Herbert Simon[18] looks forward to the time when we "discover a science of design, a body of intellectually tough, analytic, partly formalizable, partly empirical, teachable doctrine about the design process". In the discovery of this 'science' and in the study of this process, computer-based artificial intelligence will be of prime importance. This area of research is both the most challenging and the most necessary.

Design tools

Research is needed to establish an integrated data base holding the 'building description'; this would be the kernel of an 'object-oriented' system of 'tools'. Development of improved user interfaces, exhibiting intelligence in the absence of complete data, will be necessary if the design systems are to be client-oriented and facilitate user participation in design.

Validation and evaluation

Existing and emerging CAAD systems require to be validated (in terms of their reliability, accuracy, etc) and evaluated (in terms of their usefulness in practice). This research can only be conducted in collaboration with practice.

Knowledge bases

Large-scale parametric studies of the causal relationships between design and cost/performance variables require to be carried out using existing and emerging programs in an effort to establish the knowledge base on which 'expert' systems will draw and on which building performance specifications might be based.

Regulation and certification

Research is needed to anticipate the implications of the emerging generation of software tools for the form and content of the building regulations and the appropriate degree of self-certification by architects and engineers.

Power shifts

Finally there is a need to study directly the nature of the power shift which CAAD will bring. To quote Cooley[11]:

> . . . The reality is that as we design technological systems, we are designing sets of social relationships, and as we question those social relationships and attempt to design systems differently, we are then beginning to challenge in a political way power structures in society. The alternatives are stark. Either we will have a future in which human beings are reduced to a sort of bee-like behaviour, reacting to the systems and equipment specified for them; or we will have a future in which masses of people, conscious of their skills and abilities in both a political and technical sense, decide that they are going to be the architects of a new form of technological development which will enhance human creativity and mean more freedom of choice rather than less. The truth is, we shall have to make the profound political decision as to whether we intend to act as architects or behave like bees.

OVERVIEW

Table 1 attempts to summarise the time-scale relevant to actions and outcomes in CAAD. It may be used to anticipate the research and educational initiatives which will be appropriate if the impacts of the technology are to be beneficial rather than harmful. Such an overview should be the subject of regular updating as developments unfold.

ACKNOWLEDGEMENTS

The author, on behalf of the eCAADe, wishes to thank Andre Kirchberger of Directorate General V of the CEC

Table 1. Time-scales for actions and outcomes in CAAD

	Immediate (now)	Short-term (5 years)	Mid-term (5–10 years)	Long-term (10+ years)
Technology	Micros Drafting system Performance models	Supermicros Partially integrated systems Early expert systems	Worldwide networking Expert systems Fully integrated systems	Computer ubiquity AI and natural language systems
Applications	Spread of use of computers in offices Drafting	3-D modelling for visualisation Regulation revision	Performance specification Solid modelling for appraisal	Participation Client-oriented CAAD systems
Impacts	Expense/time to implement Job differentiation; losses and gains	Shortage of qualified people Shift from private to public sector Demise of medium size practices	De-skilling Responsibility and liabilities Breakdown of professional boundaries	Improved building performance Higher grade professionalism De-professionalisation
Education	Architectural students awareness and familiarisation System evaluation Teacher education	In-service training and re-education Clients awareness Undergraduate CAAD systems	Post-graduate and mid-career CAAD education Undergraduate syllabus changes	Computer-assisted learning in design
Research	Monitoring of spread of CAAD Evaluation of CAAD education experiments Validation of existing programs	Human-centred CAD systems Kernel and shells for integrated CAD Interfaces and knowledge bases	Systems for naive designers Computer-assisted learning systems	Optimisation in design Non-traditional ways of communicating with computers

for the opportunity to produce a report on such an important topic. The hard work in organising the international meeting was carried out by Geert Smeltzer (CALIBRE Group, Technicshe Hogeschool Eindhoven) and Hendrika Buelinckx (Vrije Universiteit Brussel). The participants at the international meeting were Nigel Cross (Open University, UK), Albert Dupagne (Universite de Liege), Helmut Emde (Technische Hochschule Darmstadt), John Gero (University of Sydney), Lamond Laing (Robert Gordons Institute, UK), John Lansdown (Royal College of Art, London), Frank Oswald (Greater London Enterprise Board), Matti Poyry (Rakenusalan CAD, Helsinki), Felix van Rijn (Universiteit van Amsterdam), Rik Schijf (National University of Singapore), Gy Sebsetyen (CIB), Edward Smith (University of Utah) and Harry Wagter (Technische Hogeschool Eindhoven).

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