

Myth and Reality in the Use of IT and Computer Based Technologies in Construction

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"Evolution is less about optimal designs than about making do with whatever is handed down to us." Stephen Jay Gould.

ABSTRACT

IT and computer based technologies are a catalyst for focusing attention of managers on technical and commercial efficiency. It is sometimes argued that a detailed evaluation of existing practices, in itself, generates a better understanding of the factors constraining efficiency. But it is also argued that it is the computer based technologies themselves which deliver improvements in efficiency. Because the construction process is fragmented, the overall efficiency of the process might 'a priori' be enhanced by the use of IT and computer based technologies. However, this assumes that a coherent strategy for their use is in place, both within individual companies and practices, and within the wider construction process.

Our current research has highlighted a problem, within a majority of construction engineering and design organisations, which constrains the development of 'IT' beyond that of discrete applications. The lack of a coherent strategy for the integration of these technologies within a company is a major constraint on their effective use within the organisation. The integration of the use of the technologies between separate organisations within the construction process, posits problems of an even greater level of complexity.

This paper, has two primary objectives:

to articulate the major constraints to the effective use of 'IT' in order to develop a set of relevant criteria for evaluating future investments; and to examine the rationale for, and mechanisms through which, integrated systems, both within organisations and the construction process, may be introduced.

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Key Words

construction; information technology; management; technology transfer; corporate strategies

INTRODUCTION

This paper is based upon a programme of research on the application of IT and communications technologies in British and Swedish construction. The data sources used are a survey of architects, quantity surveyors and contractors, completed during the latter half of 1992, "IT and International Trade in British Construction Engineering and Design Organisations" (IPRA, 1991) and "IT and International Trade in Swedish Construction Engineering and Design Organisations" (Drewer, 1992). These last two papers were commissioned by UNCTAD for their study "Technological Change and International Competitiveness in the Construction Engineering and Design Services Sector".

IT and computer based technologies were first used, in the 1960's and early 1970's, by an 'elite' among British Construction Engineering and Design Organisations (CEDO's). Typically, by the larger contractor who used 'main frame' computers for accounting and network analysis. The technologies were also used, during this period, by some of the larger engineering design consultants, for CAD and structural design. Although, in the 1960's, these technologies were new to the British CEDO, they had previously been developed and proven in the United States. The earliest research and developments in these technologies had been generously, and jealously, supported by the US Department of Defense. Consequently, it was through the medium of defense contracts, that diffusion into the non-defense sectors was effected.

During the 1970's, the use of IT steadily proliferated and by the early 1980's, there was extensive use of CAD for design and draughting by the 'elite' companies. This was most evident among those companies who were involved in the growing market for construction in the middle east. (Drewer, 1982)

However, it was in the 1980's, following the introduction of the PC, that there was a more universal use of IT by British CEDO's. It has been argued that, during the 1980's, the technologies were considered to be, "..... a symbol of progressive management". IT was perceived as a status symbol for the company, department, or individual. (KPMG and CICA, 1989) The evidence, which is mainly circumstantial, suggests that the enthusiasm for the technologies was so pervasive that, in many cases, it was not moderated by judgement.

The expansion of the use of IT and communications technologies among British CEDO's in the 1980's, could be described as 'contagious growth'.

(see Figure 1 and Gibson and Nolan, 1974) This expansion was not uniform, neither between nor within the different segments of the domestic construction economy. There was an implicit assumption that there were unique, measurable benefits to be gained from replacing the existing methods of production and organisation with the new technologies. But it was difficult, if not impossible, to make these benefits explicit through the application of standard investment appraisal techniques.

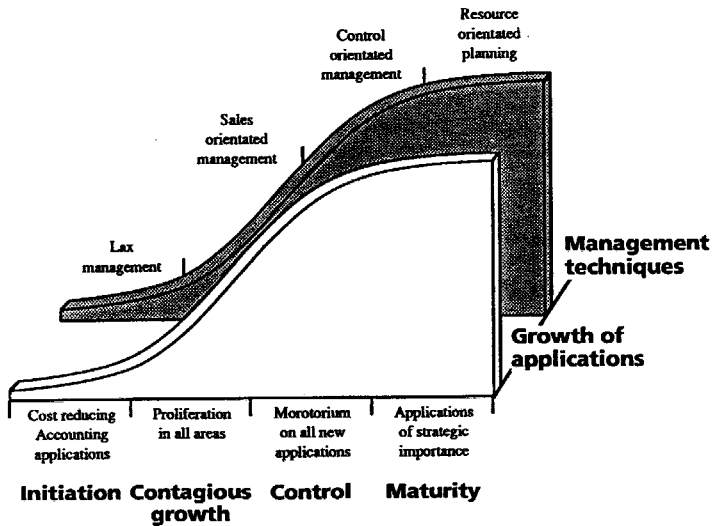


Figure 1. The Four Stages of IT Growth

Source: Gibson and Nolan, 1974

Researchers have the benefit of hindsight, they investigate outcomes, yet frequently impute 'ex ante' rationale. Our surveys, which attempt to measure judgemental factors, also reflect the views of the interviewee. It is possible that our data are records of individual prejudice rather than objective measures of reality. However, we should respect the integrity of our source of information and not assume 'a priori' that 'we know best'.

THE BRITISH & SWEDISH CASE STUDIES

These studies were focused on the implications of IT and communications technology for the longer term competitive profile of the CEDO's. They reflect the corporate views of a limited number of larger British and Swedish companies. As such they provide a profile of the attitudes of an 'elite' among both British and Swedish CEDO's.

British CEDO's

Five major British CEDO's were interviewed for "IT and International Trade in British Construction Engineering and Design Organisations" (IPRA, 1991) These companies, working from a strong domestic base, were major 'actors' in the international construction system. They tended to be 'typical' British consultants, "..... independent organisations who market a service to clients which is independent of subsequent production interests".

Those interviewed were employees of 'elite' companies and their attitudes and actions cannot be assumed to reflect those of the sector as a whole. Their view of the issues raised was conditioned by a need to, '..... have capabilities in several types of geographical region, including the industrialised economies, the so called newly industrialising countries and the developing countries.'

The summary of the conclusions identifies the following as being significant:

- British CEDO's have relatively limited IT capacity and their 'systems' tend to be an assortment of individual applications and data sets linked manually.
- General 'systems' dominate their domestic operations; accounting, word processing, financial modelling and job costing.
- Technical 'systems' for engineering calculations and an assortment of graphics based applications are also commonly found.
- The most significant problem in implementing IT has been to convince their 'very experienced' engineers that it is necessary to work in new ways.
- IT is a condition of their commissions in the markets of the industrialised countries. Clients recognise that, in addition to providing improvements in speed of delivery, IT can bring benefits in the quality of design and engineering solutions.
- There is a shift in emphasis from earlier efforts to achieve cost savings in discrete areas of operation, to a concern with the integration of IT applications as a source of comparative advantage.
- Their future plans for IT will depend on the solution of technical problems relating to standards, structural problems relating to the fragmentation of the sector and the management of the technologies.

Swedish CEDO's

Five major companies were interviewed in the parallel study of Swedish CEDO's; two engineering consultants, two contractors and a specialist project manager. Each of these companies has a major share of the Swedish domestic market and four of them are major international CEDO's. (Drewer, 1992)

The summary of the conclusions identifies the following as being significant:

Myth and Reality in the Use of IT

- There are no easily identified economic benefits associated with the use of the new technologies, but they are important in that they condition the 'attitudes' of potential clients. That is they are a 'marketing device' or a projection of the companies 'engineering culture'.
- There are no well defined criteria for evaluating investments in CAD and IT technologies. Most are 'acts of faith' rather than the outcomes of normal investment appraisal.
- CAD and IT technologies in Swedish construction are still at a relatively early stage of development; intensive collective efforts are being devoted to their development and application.
- The use of CAD for structural engineering design allows the designer to initiate a more comprehensive programme of checks.
- CAD requires a more structured system of information than that required for traditional design methods. The dynamic process of technological change would be assisted by the increased standardisation of building design.
- The opportunities and problems associated with the use of CAD and IT technologies in construction, significantly differ by type of work. It is not obvious whether the observed imbalance in progress between types of work, is a function of technical factors or whether it is market driven.
- CAD and IT technologies and construction engineering and design are 'mature industries', but their juxtaposition has resulted in the creation of what is, in many ways, a new 'infant industry'.

Both these studies identify extensive and intensive use of IT in the areas of 'general applications' and intensive, but less extensive, use in the area of 'technical applications'.

A SURVEY OF BRITISH CEDO 's

It is of some interest to consider the results of our preliminary survey in the context of a similar survey of a sample of medium and large British CEDO 's, in the late 1980 's.(Building on IT for the 1990 's, CICA and KPMG, 1989)

The studies identify an 'explosion', in the use of IT and computer based technologies among British CEDO 's, between 1983 and 1989. Their data suggest that this was uniquely associated with the increased use of PC 's. They showed investment in 'main frame' computers to have reached market saturation as early as 1983. General applications were used most intensively and extensively; word processing, spread sheets, accounting, job costing and data bases. Technical applications, CAD, specifications, project management and structural analysis, were used both less intensively and extensively. (Table 1)

Table 1. Incidence of Software Use

System	Architects	Q.S. %	Building Contractor %
Word Processing	97	96	85
Financial Modelling	89	92	97
Accounting	73	71	100
Job Costing	68	79	27
Data Base	65	71	73
CADD	81	17	9
Project Management	41	67	33
Estimating	3	13	42

Source: KPMG Survey Data

System	All Consultants			All Contractors		
	%	%(1) Standard	%(2) Bespoke	%	%(1) Standard	%(2) Bespoke
Word Processing	92	90	2	75	74	1
Financial Modelling	81	70	11	77	67	10
Accounting	70	56	14	88	78	10
Job Costing	68	45	23	23	19	4
Data Base	67	59	8	51	48	3
CADD	59	53	6	17	16	1
Project Management	47	44	3	39	32	7
Estimating	12	8	4	44	30	14

Source: "Building on IT for the 90's" 1989 Survey Results

- Notes:**
1. 'Standard': Standard packaged software.
 2. 'Bespoke': Systems written in house or standard packages tailored to individual needs.

There were differences in the problems associated with the use of IT and computer based technologies, identified by the different sub-groups in their sample.

Contractors identified 'locating suitable proven software' as their major problem, followed by 'quantifying the benefits of investments', 'lack of

understanding of the construction industry by software support staff' and 'lack of staff with both industry and IT training'.

Consultants identified 'quantifying benefits' as their major problem, followed by 'locating suitable proven software', 'adoption of standards for the exchange of data' and 'lack of staff with both industry and IT training'. (Table 2)

Table 2. Problems with the Use of IT

Problem Area	%	%
	All Consultants	All Contractors
Finding Suitable Software	52	69
Unable to Quantify Benefits	58	53
Suppliers Lack of Industry Knowledge	34	49
Inadequate Training	38	40
Obtaining Value for Money	34	25
Software too Difficult to Use	22	7
Other Problems	5	5

Source: "Building on IT for the 90's" 1989 Survey Results

Our 'field work', which is some four years on from that of KPMG and CICA, was structured to provide data which covers a wider range of British CEDO's. The sample includes 41 architectural practices, 32 quantity surveying practices and 94 contractors. It also includes a broad range of companies by size and location. Of the 94 contractors in the sample, 30 claimed that they did not use any IT or communications technologies. These were all small companies, employing less than 30 people and located in the northern counties and Wales. They were not included in the preliminary analysis of the data. Some IT and communications technologies, albeit with differing degrees of intensity, were used by all but three of the companies included in our analysis. General applications were the most intensively and extensively used; this was most apparent in the use of computers for word processing.

Among the sample of quantity surveyors, word processing was followed by the use of packages for accounting, data bases, and job costing. Among the sample of contractors, word processing was followed by the use of packages for accounting, job costing and data bases. The sample of architect's use of general applications was less extensive and intensive than for either of the other two groups; word processing being followed by the use of packages for data bases, accounting and job costing. The architects use of data bases was

comparable to that of the contractors. (Table 3)

With respect to the more technical applications, a much greater diversity was apparent, albeit at a lesser level of intensity than was the case with the general applications. Contractors used IT more frequently for estimating and project management than did either the quantity surveyors or the architects, whilst architects were the most prolific users of CAD.

Table 3. Incidence of Software Use

System	Architects			Q.S.			Bldg Contractors		
	%	% Std	% Bspk	%	% Std	% Bspk	%	% Std	% Bspk
Word Processing	100	88	12	100	97	3	94	90	4
Accounting	59	31	18	82	57	25	87	32	55
Job Costing	57	18	39	78	38	40	79	32	47
Data Base	66	48	18	81	50	31	68	40	28
CADD	81	73	8	38	32	6	32	26	6
Project Management	39	33	6	51	40	11	51	40	11
Estimating	12	5	7	44	22	22	59	34	25

- Notes:
1. 'Std': Standard packaged software.
 2. 'Bspk': 'Bespoke' systems written in house or standard packages tailored to individual needs.

For general applications the bias was towards the use of standard commercial software, but there were many 'in house' and 'tailored' packages used for accounting and job costing. CAD tended to be provided through the use of standard commercial software, but much of the software used for project management and estimating, was developed 'in house'.

The explanation for these variations probably resides in the 'maturity' of software engineering for general applications. Word processing, accountancy and data base software are not uniquely focused on construction; they are sectorally neutral. They are 'mature' applications which are probably more complex 'software products' than the software required for many technical applications. Sectoral neutrality and the maturity of the commercially available 'software product' leaves the CEDO with little rationale for specialist 'in house' software development.

Another factor which our data identify is the development cycle of computing within the British CEDO. As we have previously noted, many of

the larger CEDO's, particularly the contractors, had used 'main frames' for accountancy and general management functions since the 1960's. Typically, they would have had 'bespoke' software written for these applications. With the advent of the PC, more specifically the networked PC's with the capacity to replace the functions being performed by the main frame, they had to manage the 'move away' from the main frame. This has still only been achieved by a few companies hence, many companies are operating with 'mixed systems'.

There was a wide diversity of rates of expenditure on IT in the sample of CEDO's. Most allocated less than 1% of their turnover to IT; 56% of architects, 86% of contractors and 92% of quantity surveyors. This relationship was not constant between the three groups. There was a positive correlation between proportion of turnover spent on IT and company size among the quantity surveyors, no clear relationship among the contractors and an inverse correlation among the architects.

Similarly, there was a size factor involved with respect to specific uses of IT. The intensity of IT use by quantity surveyors and contractors increased with size of company. The one exception being the more wide spread use of data bases by the smaller quantity surveying practices. Among architectural practices, the use of IT tended to have a more even spread across the size range.

Companies were asked to identify the major problems which were constraining the effective implementation and extension of their uses of IT. They identified the 'quantification of costs and benefits' to be the most important, followed by the 'locating suitable software' and a 'lack of knowledge of construction practices and procedures among suppliers of hardware and software'. This was more apparent among the contractors than among the architects and quantity surveyors. (Table 4)

The factors which they considered of least importance were those among which many of the 'IT myths' reside. Senior managers were not considered to be a 'major barrier', nor did they consider that there was a training deficit. Finally, they did not consider there to be major problems in selling the idea of using IT to their staff.

If we compare these results with those of the earlier KPMG and CICA study, we note a perceptible shift in attitudes. Construction specific factors, such as 'lack of building industry knowledge by software suppliers', are moving down the 'problem hierarchy'. The 'naive user' factors, such as 'finding suitable software' and 'software too difficult to use', are also moving down the 'problem hierarchy'. 'The quantification of costs and benefits' is now identified as the most important problem in the IT decision making calculus.

Table 4. Problems with the Use of IT

Problem Area	% Building Contractors		
	% Architects	% Q.S.	% Building Contractors
Unable to Quantify Benefits & Value for Money	46	56	61
Finding Suitable Software	25	16	35
Suppliers Lack of Industry Knowledge	32	41	33
Software too Difficult to Use	17	13	17
Senior Management Awareness	0	0	4
Inadequate Training	5	0	2
Other Problems	12	9	13

Our evidence suggests that software applications are more closely meeting the needs of the CEDO's and that the degree of computer literacy within CEDO's has significantly increased. Some of the larger contractors in our sample stated that, "..... in future we shall use 'off the shelf' packages and they will not be modified". However, there is also evidence from the survey that quantity surveyors were seeking, "..... systems that emulate traditional methods, those which replicate the old 'paper processes'." There were more 'tailored packages' used in the sample of quantity surveying practices than in that of either the architects or the contractors.

Our research has also identified a 'cultural shift' relating to the perception of IT and computer based technologies by British CEDO's. In 1964, the larger contractors, who were then moving into the use of 'main frame' computers, formed a steering committee to, "..... develop a common set of industry standards with respect to the use of data processing equipment."

That is 'construction for computing' as distinct from the presently dominant view of 'computing for construction'.

THE GENESIS OF A STRATEGY

Although IT and computer based technologies are international in intent and effect, they typically had their first commercial applications, during the 1960's, in the United States. This was a consequence of US economic power and the scale of their military research effort. Applications tended to be introduced first in the United States, which provided a bench mark for others in determining the desired and the achievable. The earliest experiences of IT by the larger British CEDO's, were in areas where there was such a 'US bench mark'; 'main frame' technologies for accounting, network analysis

and structural design. This required a significant level of investment in hardware and either the purchase, or development, of dedicated software for the targeted applications.

Prior to the introduction of the PC in the early 1980's, the use of IT and computer based technologies by British CEDO's was limited both in terms of numbers of systems and variety of applications. The period between the 'main frame' and the PC was not some 'silicon' equivalent to the 'dark ages', neither in IT nor in it's uses in construction.

The most significant advances were probably in general applications, although there were important developments in technical applications. The mini-computer extended the use of computing technologies for word processing and data handling procedures. More sophisticated software and networked terminals, introduced a wider range of users to computing.

The framework for the 'age of the computer' was in place but the advent of the 'age of the computer' was consequent on the introduction of the PC. The 'contagion' of the 1980's, was founded on the introduction of the first PC's and the economic changes which this initiated. The economic dynamics of computing changed dramatically. There was a large market for the PC, much larger than expected and the pervasiveness of it's use was reinforced by falling prices, in both absolute and real terms. Also, there was a coincident growth in demand for, and production of, PC dedicated software.

Computing in the 1980's was characterised by major advances in the technology of both hardware and software, the creation of an international software industry and infrastructure and falling prices, in absolute and real terms. Prior to the introduction of the PC, computer hardware costs dominated user profiles. But with the advent of the PC the costs of computer hardware fell dramatically and the possibilities for software applications exploded.

The earlier circumspection gave way to enthusiasm, a new dawn had arrived. The economics of the PC stimulated an increase in the use of IT both among and within companies. But a similar pattern of computer use emerged to that of the earlier uses of 'main frames'. General applications supporting discrete operations, such as accounting and word processing, followed by the equally discrete technical applications, such as CAD, project management and cost planning and control.

It is argued that during this period, strategies for IT and computer based technologies did not appear to have been a major concern of senior management. This apparent lack of concern among senior management is a mystery. It might suggest, that the 'bottom up' nature of the diffusion of IT and computer based technologies in CEDO's, precludes the early involvement of senior management. However, it does not seem likely that the earlier decision, by many of the larger CEDO's, to invest in extremely costly main

frame technologies, would have been made at the lower levels of management. It is conceivable, given that PC's are relatively inexpensive, for the growth of investment in IT in the CEDO's to have been more of a process of accretion. Probably, we are observing, 'ex post' a whole system, which 'ex ante' was conceived as a separate, yet rational, sub-system.

For many, the main diagnosis has been to identify the lack of an overarching strategy for IT in British CEDO's, as an impediment to the effective use of these technologies. This assumes that the existing configuration of IT within companies is sub-optimal and that the solution to the IT problem is the introduction of a company wide integrated strategy. But it is also conceivable that more integrated systems will evolve, as hardware and software become more sophisticated and standardised.

The implications of the use of IT within companies, on their organisational structure, is self evident. But it is important to recognise that the primary operational objective of the CEDO, is to design and produce buildings and civils works. IT must be used to service these functions, not to dominate them. It could be argued, and probably should be argued, that the greatest benefit to be gained from the evaluation of IT, is in the analysis of the broader operations and objectives of the CEDO.

The 'quantification of benefits' argument subsumes the more important requirement, of the need for continuous evaluation of company objectives and how these are to be satisfied. It is true that the impact of IT is pervasive, and its use implies changing relationships between the operational departments within the CEDO. But, it follows that a primary concern with IT strategy could have negative effects which, as yet, cannot be identified. There is a need for a sense of proportion. IT strategies, partial though they may be, should evolve in parallel with the broader corporate objectives.

Some argue that the main problem is the fragmented structure of the construction sector. 'The preservation of intra and inter organisational barriers, often results in individual users and organisations, producing data in a way which suits their own needs and yet has no real benefit to other users within the same organisation or project team. Fragmentation may therefore be seen as a key 'inhibitor' to the effective use of advanced information systems within the sector.' (KPMG and CICA, 1989)

But it could be argued also that fragmentation in the sector is a rational response to the complex of problems which reflect the 'facts of life' of construction. Therefore, should the structure of construction be changed to accommodate IT or should IT be used to facilitate more effective information flows through the complex process termed construction; computing for construction or construction for computing?

CONCLUSIONS

The sequencing of the development of the use of IT and computer based technologies by British CEDO's is now well established.

Phase One

The 'elite' companies invested in 'main frame technologies in the 1960's and 1970's for general applications and some limited technical functions.

Phase Two

Steady expansion among the 'elite' with limited extension of use for general and technical applications.

Phase Three

The advent of the PC and the significant increase in the use of the technologies with little apparent concern for the formal commercial viability of the investment.

Phase Four

The shift towards a more commercial attitude to investment in IT and computer based technologies at the end of the 1980's and into the early 1990's.

The earlier investments in main frame technologies were by the 'elite' of market leading companies. They tended to rely on systems and applications which had previously been proven in the United States.

This was a rational yet cautious response to the new and unfamiliar technologies. For a period of nearly twenty years, the rate of growth in the use of the technologies was modest and relatively easy to accommodate. However, it was the advent of the PC which stimulated a major shift in procedures and practices among British CEDO's.

It was inevitable that the first stage of investment in software for PC's by the British CEDO's, should be for discrete, general, applications. There existed the required 'critical mass' of hardware, software and the supportive infrastructure, to make this an acceptable risk. But in the early 1980's, 'applications' possibilities exceeded the capacity of the existing 'applications software'. But now there is more congruence between 'applications' possibilities and 'applications software'. A symbiotic relationship has developed between applications software and the identification of applications possibilities.

During the early days of the PC the bias of commercial software was towards general applications. There are now, following the development of a more comprehensive software development infrastructure, more commercially available software 'products' for technical applications. Recent experience would suggest, that a combination of developments in both computer hardware and commercial software will reduce the need for 'bespoke' software, for most of the standard applications required by the CEDO's.

The use of IT and computer based technologies identified by our survey,

may be structured around a specific 'product mix'. For example, commercial and industrial construction for the private sector client dominated the 'product mix' of the British CEDO's in the 1980's. The use of the technologies was linked to client requirements in terms of lead times and project duration, size of project and systems of cost control, and the 'international' standards of design which were so prevalent.

We cannot assume 'a priori' that any other configuration of projects and clients would have stimulated a significantly different interface with IT and computer based technologies. The evidence from the late 1970's is that there is a strong diffusion of significant technological and procedural changes within construction, beyond the types of work and circumstances for which these technologies were originally introduced.

Objective appraisal of investments and strategies which seek to rationalise the IT profile within CEDO's, are self evidently desirable. Doubts concerning integration are well founded but they should not preclude the imaginative investment in alternative 'futures'. We are still at an early stage of IT development in construction and must recognise the 'infant industry' problem.

The richness of IT is such that 'making do with whatever is handed down to us' is probably preferable to a Quixotic pursuit of optimality.

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