Strategic Information Technology Planning for Computer Integrated Construction

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Abstract

This paper explains what is meant by the strategic use of information technology (IT). It describes the background to making strategic use of IT tools in future by outlining and commenting on the use that has been made of them until now in the construction sector in Singapore. It offers suggestions regarding how strategic use of IT in construction can be brought about by initiatives from government agencies, professional institutions, and private enterprises through the use of some case study examples. The benefits of strategic IT use, are set out, as are the effects it may have on restructuring within the industry, the professions and enterprises, and its possible influence on productivity and organisational competitiveness.

The Strategic Use of I.T.

Much of the pre-occupation of researchers in computer integrated construction (CIC) appears to be with the two issues of technological development and data coding and classification standards. In this paper we argue against these priorities. The major problem as we see it is not with the technology and technical exchange issues but with the management, policy-making, procedural and strategic issues of how IT can integrate construction activities and enterprises. The aim of the paper is to define what is mean by strategic use of IT and to show how this can be achieved at both enterprise and national levels.

Strategic Goals and Benefits

Some use of IT has reached almost every organisation in every sector of the economy in one form or another. In most sectors, IT is being used as a support activity to improve productivity and reduce costs of operation, including labour costs. Most of these activities are in the form of accounting, word-processing and telecommunications such as facsimile. However, in some industries IT is being used strategically. IT's potential to be a strategic weapon to gain competitive advantage is still untapped in the construction industry. The main message from this paper is that we should concentrate our plans for the future on identifying and developing strategic uses of IT rather than simply trying to automate and integrate current processes. In the construction process, the potential strategic use of IT is in areas such as the ones discussed below.

Reducing Project Cost and Time: Cost and time overruns are common in the construction industry. Early completion of a project - starting from design to construction to handover to the client - is a definite cash flow advantage. IT can assist in overall project planning and control, and achieve a reduction in cost and time. Scheduling of activities, coordinating delivery of raw materials, components, and equipment; and monitoring site activities in view of unforeseen delays can be done using IT. It is also possible to jointly

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monitor several different projects and optimize the company's resources by sharing these among all on-going projects. This requires effective coordination and project monitoring which is not possible without the use of appropriate IT tools.

Quality Product and Value-for-Money: Every client wants value for money. Quality in construction can be achieved through better control and coordination among various professionals collaborating in the design and construction of the built-form. The lack of communication among collaborating consultants is well known, and with a sequential chain of design stages, expensive and wasteful solutions tend to be adopted and further developed by professionals downstream, because the concept plan cannot be changed. Expensive and sub-optimal structural and mechanical and electrical services designs, are often used where a cheaper solution could have been provided. Considerations of buildability and maintenance requirements are not fully taken into account, leading to higher costs or delays.

In most cases a speculative client desires and demands a product with the lowest initial cost. But for an owner occupier it is the life-cycle cost, which includes maintenance and operation costs, that gives a true measure of economy. Taking this view, the maintenance and operation costs have to be integrated, and this calls for suitable, integrated cost databases which need to be used in life-cycle costing. An organisation which has access to such databases, which is now becoming possible through IT networks, will be in a position to provide better value for money to the client. It may also be possible to more easily sell the building as a product on the basis of its information relating to life cycle costs. The new situation is that more and more clients may start using life-cycle-costs as a measure of quality, and organisations which provide this service may have a competitive edge over those who do not.

Integrated Design/Management Database: Maintenance and facilities management can be adequately assisted by IT since a graphics database can keep visual information on various building facilities, and maintenance and repair needs and associated costs can be kept in a database. If the original design was produced on a CAD system, the management database can be added-on to the CAD database. Thus an organisation that provides its designs on CAD will have a distinct edge in selling this to a client who wants to use IT for the management of the property as well.

Creating Market Niche: Construction organisations that develop one or more of these strategic IT applications would carve a niche in the market. Niche strategies are one means of obtaining a competitive advantage. One niche may be in services for specialised projects that require complex coordination and control. These may be projects which are either of a specialist nature (such as a military or a scientific research facility) or a project on a very tight schedule. Construction organisations should therefore examine the strategic IT applications and aim to adopt those that are believed to be critical to the success of the organisation in creating a market niche.

This brings us to a whole new area of strategic use of IT. Following the new strategic planning techniques that have evolved for the new globalized and dynamic business environments [Flaaten 89], there is scope for national construction industries and construction firms to gain competitive business advantage through IT. Both could look to use IT as a means of increasing the value-added contributions of their activities and to strategically position themselves in relation to the changing market forces to be found in their industry segments. They could explore the opportunity IT gives for generic competitive strategies such as differentiated products, product and cost focus, and overall cost leadership. This could be done by individual local firms or by the industry as a whole. Thus, IT has strategic implications for the construction enterprises following principles set

out by Porter and Millar [Porter 85]. The construction industry has an opportunity to strategically exploit IT by examining how this can play a part in the "polishing of the diamond" [Porter.90]. It is now pertinent to take note of the particular hindrances presented by construction.

Hindrances to strategic IT use in construction

The sectors where IT appears to have made most dramatic impact are where other major forces for change also exist. Some examples of these are quoted [Earl 89]. Deregulation of airline and financial services; the need for global survival in automobile manufacture and textiles; and the structural changes that are effecting retailing are all quoted as forces which are leading some organisations in some sectors in some countries to use IT as a strategic response.

A further prerequisite for strategic use, and a symptom of an organisation having entered the IT era, is stated as the technology having permeated all functions and levels within an organisation. Early uses of data processing (DP) were restricted to distinct DP departments and for specific number-crunching applications. Organisations that have more fully embraced IT are now in a situation of having a range of hardware and software technologies being used by a diverse range of groups of people and for a variety of different tasks and activities.

In construction this is far from the case. The majority of construction organisations still appear to have IT being used by IT specialists or for discrete applications and it would seem only by staff at the technical levels. This situation has been borne out by different studies [Chow 89] and [Peat 90]. Both observed that IT is still restricted to administrative functions of an accounting nature or for highly specific and technical functions within the construction disciplines.

On this basis it must be concluded that the construction sector is a long way from having reached the IT era, or being strategic in its use, and that a significant change is needed in the variety of levels of management that are using the technology and the diversity of functions to which it is being applied. For this to be possible will require all construction organisations to reconsider their size, organisation structure, recruitment policy and their education and training activities in the light of their requirements in the IT era. Few appear to have done so as yet. The solution of the problem is only partially to be addressed by developments in standards and technology.

Some sectors of the economy such as financial services, particularly personal banking, are fast approaching the stage where IT is critical to the success of entire operations within enterprises. In others, IT plays a much more supportive role to activities. IT is a support activity if it is not critical to either the current operations of an organisation nor to the strategic plans for development of that organisation. IT is used strategically if it is critical to both current operations and future plans for strategic development.

Several studies have shown that many construction enterprises consider that IT has not made a significant impact on their activities [Chow 89]; [Peat 90]. However, there are isolated examples of some construction sector organisations making IT a critical part of their strategic development plans if not of their current operations. Koskela [Koskela 85] describes the detailed plans of a number of Japanese contracting firms who are clearly planning to exploit the full range of IT including data processing, telecommunications and automation technologies. Hasegawa [Hasegawa 89] also describes the strategic place of IT for other Japanese construction firms.

Other writers have commented on the strategic opportunities that IT gives to business organisations [Porter 85],[Ives 84]. Betts et al [Betts 91] show how some of these concepts apply to the construction sector. An organisation looking to use IT as a strategic weapon can look to improving its internal or external productivity or competitiveness to create new opportunities for itself. Most construction enterprises seem only to be examining IT as a means of improving internal productivity. Governments, professional institutions and groups of enterprises may have more opportunities to examine external productivity. The Royal Institution of Chartered Surveyors (RICS) in the UK provides a further example of how this can be done. The Building Cost Information Service is a central database of price information supplied by subscribing members who are all able to exploit the shared data to improve their individual productivity. The external productivity of all surveying enterprises is thereby improved and it could be argued that the better quality of data also improves their competitiveness. The work of the Singapore Institute of Surveyors and Valuers (SISV) on the Building Price Guide (SISV, 1991) is an attempt to offer a similar service, albeit at present only in a hard copy format. The guide contains building resource prices, measured work rates, details of price and cost indices and details of how the data has been collected including a list of suppliers responsible for resource prices. The intention is that this will eventually be available in a diskette format.

The Royal Institution of British Architects (RIBA) is offering a similar form of strategic use of IT through the RIBACAD system [Ray-Jones 90]. This has obvious benefits to external productivity but not really to external competitiveness. Similarly, the Design Support Centre established by the Singapore Institute of Architects with the Construction Industry Development Board (CIDB) will address some aspects of external productivity for architects in Singapore.

There are many isolated and individual examples of enterprises and projects where IT is being used for small improvements in internal productivity. The area where construction organisations appear to be failing to exploit IT strategically is for their internal or external competitiveness. Few appear to be able to offer a new or improved service by virtue of their IT use and even fewer to consider new ways of managing and organising themselves or to develop new businesses. From this it can be concluded that on the basis of IT being a potential strategic weapon, the construction sector falls short of having fully arrived in the IT era.

We have therefore explored a number of ways in which the use of IT can be considered to be strategic. We may be able to illustrate some of these points regarding strategy by using Singaporean case studies of organisations and their approach to IT use and development.

Information Technology in Singapore

Singapore has already recognised the beginning of the information age [Daniels 91]. The National IT Plan (NITP) was launched in 1986 by Brigadier General (Res) Lee Hsieng Loong at the opening of Singapore Informatics, 1986. It provided a blueprint for an action programme that calls for the exploitation of IT to develop a strong export-oriented economy. The NITP has seven interactive building blocks, namely IT Industry, IT Manpower, Information Communication Infrastructure, IT Application, Coordination & Collaboration, IT Culture, and Climate for Creativity & Enterprise.

The construction industry, falls under the IT Application Programme, under which three strategies were developed:

a) build up an extensive information infrastructure to enhance the usefulness of IT;
b) promote IT as a means to increase productivity and business competitiveness; and
c) extend the public sector computerisation programme to encompass users in the private sector.

The NITP set out a challenge to all sectors of the economy to develop their use of IT resources in a nationally coordinated manner. The construction sector should take up this challenge to work towards the success of the NITP and how the three strategies proposed under the NITP can be adopted for the industry. Considering the fragmented nature of the construction industry, and the peculiarities of the construction process, this will be a challenging task.

The government, since the launch of the NITP, has taken steps to provide the necessary support to the seven building blocks in the NITP. An excellent information communication infrastructure already exists, and IT is almost a culture within an industrial climate that is conducive to creativity and enterprise. The National IT plan has more recently been followed by the IT2000 initiative whereby the National Computer Board has undertaken a series of sectoral studies and overall assessments of the strategic plans necessary to make sure that as a nation Singapore is using IT effectively.

Electronic Data Interchange (EDI) has become a reality with the start of TradeNet, a nationwide EDI network for the trading community, in January 1989 [Daniels 91]. A similar network for the health care industry, MediNet, and LawNet for legal services have been developed and implemented. Other networks are planned for other industries. A civil service electronic network to serve the various government departments is also being developed. While the use of EDI in construction is currently lagging behind many other sectors, the potential is considerable. The Singapore government's initiative in the development of the Singapore Land Data Sharing Network (SLDSN) is a step in the right direction. This will support a full range of land management solutions rather than simply automating maps. It is important to understand the role of private sector organisations within such EDI networks and how such networks will operate within the larger information system within the construction industry. Such networks must communicate with other information systems used in the construction process, and not be stand-alone systems.

The sectoral study for construction and real estate of the economy-wide IT2000 project was part of the overall national strategic IT planning exercise which resulted in a report with a series of recommendations. These include a value-added computer network that has been given the name COREnet. This stands for the Construction and Real Estate Network. This is intended as a textual and graphics data exchange mechanism that will embrace information services and EDI services. There appears some overlap here with BuildNet and one may assume that this more ambitious plan may subsume the BuildNet initiative. The construction and real estate sector IT2000 report [NCB 91] also contains recommendations for a number of CORE Integrated systems and CORE Business systems to support various construction activities. This is clearly the most ambitious planning for IT use in the construction sector in Singapore to date.

Thus two conclusions emerge. First, that many have been concerned with isolated and individual developments that are causing 'islands of information' to form. The IT2000 work is the first industry-based attempt to counter this. The second conclusion, that also

applies to the IT2000 initiative to some extent, is that most previous developments have concentrated on computerising or automating the current manual processes rather than considering the opportunities that IT offers to improve the effectiveness of the industry from a strategic point of view.

Case Studies of Construction Enterprises Using I.T.

We can now examine the situation in construction enterprises through some case studies.

A Quantity Surveying Firm

Background

The Rider Hunt group is an international partnership of quantity surveyors and cost consultants with offices throughout the Asia Pacific region. The organization began operations in the United Kingdom over 200 years ago. Besides providing cost consultancy services, the firm also provides project management, construction programming and estate agency services. In Singapore the group operates under the name of Rider Hunt Levett and Bailey (RHLB).

To meet its needs for IT tools, the group originally had its own in-house software development in Adelaide, Australia. A number of productivity tools for tender document preparation and for cost estimating were developed and adequately served the partnership's needs for savings in cost and time in carrying out its traditional activities. These original tools are still being used in the Singapore office and include a tender document production and contract administration tool called RIPAC and an estimating system called EVEREST. Both were developed based on the methods of document preparation and estimating that are followed by the Rider Hunt group. They were designed such that there was some link between the packages and that their upgrading and further development could be integrated. The software quickly become known outside the organisation and it was clear that other competitor consultancies and also contracting organisations would be pleased to acquire the software for their own internal productivity improvements. Many did so and both EVEREST and RIPAC are now common systems within Singapore and in Hong Kong, Australia and the UK.

Because of internal conflicts within the Rider Hunt group and to deal with this growing demand, CSSP Pty Ltd was established as an independent construction industry software developer based in Adelaide, Australia in 1983 and it has since expanded and developed its range of productivity tools to embrace those for architects, engineers, sub-contractors, project managers and clients. It is now a fully independent organisation from the Rider Hunt group and continues to develop and market its products to all organisations. Members of the Rider Hunt group are now charged full costs for acquiring updated versions of software they originally developed and for new products. The distributor of CSSP Pty Ltd products in Singapore is now a rival quantity surveying practice to RHLB.

A recently developed product by CSSP is a system called CLIENT. It is designed to provide total project management for the client by acting as a central monitor of the status of information production and circulation between all members of the project team. The system is being marketed to architects, engineers, quantity surveyors and builders but most importantly to clients themselves. Clients choosing to use the system are then stipulating that use of the software is compulsory to all other organisations when engagement terms are discussed. As many as eight individual organisations including the client, project manager, architect, engineer, quantity surveyor, builder and sub- contractors can

communicate with each other if each has a dedicated terminal and modem link. The terminals, modems and software used by the client and all of the participants are paid for by the client and treated as a project overhead. All communications regarding the status of the project during its design and construction are to be made through the system and to be monitored by the client and the project manager.

This is an example of and individual private sector organisation making IT critical to the current and future activities of others. It shows how a quantity surveying firm's computing organisation is able to extend its activities to strategically exploit the technology. It is being used on projects in Australia, Guam and soon in Singapore but is not being driven by the Rider Hunt group. It is a strategic new development and an exploitation of the new business of project management. There are several project management organisations, including Savant Pty Ltd and Tom Crow Associates, who are jockeying for the position of being able to exploit this new technology for their own gains and competitive advantage.

Extent of Use

This case study describes the way that IT is typically used by a quantity surveying organisation for productivity improvements to its traditional activities and for some limited strategic activities. However, the examples demonstrated in the case are a few of a much greater number of examples of how IT could be used strategically be a quantity surveying organisation. Rider Hunt carries out the full range of activities typical of a Quantity Surveyor. One of the prerequisites to the strategic use of IT stated above is that IT should embrace all functions and levels of an organisations activities and that it should be a high expenditure activity.

In the Singapore office of the Rider Hunt group, a mini-based computer set-up with access by all technical and professional staff is available for tender document preparation, contract administration and estimating. This system includes an extensive library and database of internal price data and standard descriptions from past projects and is used for much of the core technical activities of the firm as productivity tools. In addition, a number of separate PC systems are available for discrete applications of spreadsheets and word processors for research purposes, for company accounts, and most particularly for presentation purposes. The system is heavily printer oriented and all processing is done with the aim of improving the productivity in producing printed documents. The internal productivity of the firm is served by these systems. The organisation spent 2.87% of its fee income on IT in the period of 1983-1990. This level of investment is average compared with the construction industry generally but low compared with industry leaders in other sectors presented by Earl [Earl 89]. RHLB could be considered an industry leader within Singaporean quantity surveying firms. There is no IT-based enterprise information system within this organisation.

If such an enterprise information system were to be developed it would embrace; minutes of internal meetings, monthly progress reports from the Accounts department, projections for workload and resources, market reports, details of fees, employee performance reports, full records of past projects, details of information received from other consultants with dates, standard price details, standard contract forms, standard pre- qualification forms, contractors performance records, model documents, staff time sheets, minutes of project meetings, petty cash claims, leave application forms, recruitment details and correspondence, employees records and particulars, project progress reports, clients particulars, project details, company accounts, etc. To link all of these within an enterprise information system would be a computer integrated construction enterprise which may be a more significant business goal than CIC as we currently use the term. Some of these areas

of information are already contained within word processing and database systems within the firm but not on an integrated system linked to the main technical tools used.

Strategic Applications

In evaluating the use of IT by RHLB, one can also consider how strategic it is with regard to its effectiveness with coordination and communication of information between the diverse participants on which RHLB is involved. In this regard there is no use of IT at all although the developments by CSSP of the CLIENT system holds some promise for the future. Other quantity surveying organisations are equally able to acquire and exploit this software and one could argue that Rider Hunt have lost the opportunity of exploiting competitive advantage in allowing the CSSP group to develop independently. All existing tools, whether they be the technical productivity tools or the general business packages, are used for producing hard copy documents for transmission to other parties. There is similarly no use of IT to capture or receive data or information from other parties. This of course is not the fault of the quantity surveying organisation alone but of the broader industry in which it operates but it does illustrate the problems in strategically exploiting IT.

Areas in which IT could be used to communicate with other members of the project team are too numerous to describe although the effect on efficiency and effectiveness of projects and its contribution to design and quality cannot be overstated.

One can examine the potential this organisation has to capture and receive information from Industry level information systems that may evolve in the future. Some of these systems may be developed by the SISV and these may embrace information including: directories of quantity surveying partnerships including their past working experience and current workload, professional recruitment services, standard model documents to be shared between enterprises, materials price lists, supplier's details, tender price and building cost indices, and other data. Information systems that may be provided or collected by governmental organisations may include information such as: final account and contract award details, cost and price data, and applications for Factory licences and other statutory applications at the pre-commencement stage.

The activities of the organisation have been improved from a productivity point of view with the use of some of the tools described but our analysis shows that there are many areas where the organisation's activities could be simplified by the rationalisation that would come from an overall application of IT. These would include: the current activities of distributing monthly progress reports on accounting details, receiving performance reports for employees, receiving tender documents, sending pre-qualification questionnaires, typing and proof- reading, comping and squaring, printing and sending tender documents, preparing financial statements, receiving applications for petty cash and leave, receiving job applications and applicants details, updating personnel and accounts details, calculating and issuing pay details, and compiling and distributing reports.

The organisation is making no use of expert systems or artificial intelligence technology at present although analysis suggests a number of areas in which this would be possible. These include the preparation and analysis of preliminary cost estimates, evaluating the use or adoption of alternative components and designs, in determining the type of contract to be used, and in preparing financial statements. There are likely to be other ways in which expert systems and artificial intelligence could be used strategically by a quantity surveying organisation particularly in exploiting new business and in offering new services.

In summary, this case study shows that this organisation is one that uses IT for a limited range of its activities and for improving its internal productivity only. There is little

strategic use of the technology although there are opportunities to do this to offer new services and gain a competitive advantage. The major obstacles to strategic use of IT appear to have been a failure to commit sufficient resources, the lack of a management view of the IT problem, IT only being used for a range of levels and functions, and a failure to exploit the most recent technology. The obstacle does not appear to be that the technology is not sufficiently advanced. This organisation represents some of the best practice of IT use by quantity surveyors in Singapore by virtue of the length of their involvement with the technology and the size and nature of projects with which they have been involved. Despite this, by a number of criteria its use appears limited.

An Architectural Practice

Background

As one would expect, application of Computer Aided Design (CAD) software is critical to the needs of an architectural practice since up to about 25% of the manpower cost is incurred on drafting and the production of drawings. This includes the innumerable up-dates that have to be made at different stages - first to meet the client's performance requirements and then to accommodate the changes which become necessary when engineering systems (structural, mechanical, air-conditioning, etc) are analyzed. CAD systems, though now capable of drawing in true three-dimensions and simultaneously displaying plan, elevations and sections, are still unsuitable for early free hand sketching. A CAD system is used when the sketch designs arrive on the draftsman's table. Thus CAD systems have been given a new title, 'Computer Aided-Design and Drafting' or CADD.

The architectural practice, Swan & McLaren in Singapore, uses CADD extensively in its new projects. There are 8 architects in the firm out of a total staff strength of 40. Newly appointed architects are trained in the use of CADD, and given incentives through salary increments for CAD experience. With architects proficient in the use of CADD, designs need not go to draftsmen, thereby saving a lot of time in communication among staff. With a smaller salary gap between draftsman and architect, the net result is increased productivity at virtually no extra cost.

Extent of Use

The practice undertakes the full range of architectural design activities. The main system in use in the office is Architron which is an Apple Macintosh based CAD tool. It is used by both drafting and architectural staff for all new projects entering the office. An 8 workstation system has been in use in the office since 1989. Four of the workstations are used for CADD with the remainder used for administration and management purposes.

There is no formal IT-based enterprise information system within the firm. If there were to be one its contents would include: records of past projects, design briefs, minutes of design meetings, preliminary cost estimates, planning department and building control division comments and requirements, contractors' performance details, tender advertisements, progress reports, interim certificates, final certificates, and personnel and administrative details.

Strategic Applications

Communication with outside consultants is still mainly in the form of hard copy prints. Due to incompatible systems, and incompatible methods of working of different designers, sharing of data files is still not practical. The problem is more one of a lack of standardisation in working practices rather than standards of data coding and classification.

The company has been able to provide better services to its clients largely through its shorter start-up period on a project. Such prompt service builds up the confidence of clients quickly. This is a good example of the use of IT for increased productivity and better service, and thereby of maintaining its share of the market. The savings in cost on routine tasks has allowed the company to accept lower fee jobs, and thus be more adaptable to changing market conditions. Sustaining the company through a changing market is important, and it is pertinent to note that the management of the practice are of the opinion that IT has played a role in the company's stability.

With automated drafting through the use of CADD, it is also possible to take-off quantities automatically and provide estimates and Bills of Quantities. It would be possible for the architectural firm to provide Quantity Surveying services with the help of IT. Although there is a marketing advantage to provide Quantity Surveying services for turnkey projects, professional liabilities prevent this ability being exploited by the practice. Similarly, it is possible to use IT to provide other engineering design services, such as structural, mechanical and electrical. However, for similar reasons this is unlikely to happen. It is interesting to note that this practice was formerly of a multi-disciplinary nature but the bad experiences during the mid- to late-eighties construction recession in Singapore of having such breadth of staff are such that even though IT offers opportunity to exploit multi-disciplinary changes that exploit new business and services, the practice is reluctant to follow them now.

The benefit of IT-use would be to carry out approximate engineering calculations (sizes of structural members, air- conditioning ducts, etc.) at the early design stages. This would prevent major changes in design, or even abortive design, since in normal practice engineering calculations, which are done after sketch plans have been finalised, often show that the engineering systems (structural, lifts, etc.) cannot be accommodated in the space provided in the sketch plan. Data can be extracted from CADD files for such engineering calculations, though such IT- applications are not common.

While IT-tools permit it, the architectural practice will not provide other services because of professional liabilities. Thus professional practice dictates which IT applications can be used and which cannot. Office management is indeed an area where IT can save a lot on storage and manpower costs for an architectural firm. The storage, and retrieval, of old drawings and data can be a nightmare in terms of space and time taken to organise these. The use of CD-ROM and other database management applications can overcome these difficulties. The company is now looking into these IT applications.

There is no use of expert systems or artificial intelligence within the office. There is scope for knowledge-based systems to be developed and used for professional fee calculations, market feasibility studies, spatial requirements analysis, initial design proposals, on choice of procurement methods and in contractor selection.

At the industry level, the company is looking forward to the time when submission of plans to statutory agencies for approval over the national electronic network is possible. Many commercial problems will need to be solved first, such as making the drawing files write-protected to prevent unauthorised alteration of plans by any person when the file is transmitted from one department to another.

The company would also welcome public-domain databases that it can access such as on building by-laws and unit costs. In perspective, this is an architectural firm which has made some use of the services that IT can provide today, although the extent to which this is strategic is limited. Further applications, such as preparing bills of quantities and structural analysis, though technically feasible, are prevented by professional or legal

constraints. The company looks forward to greater use of IT in the future, to further increase its share of the market and for the company's stability in the highly volatile construction industry of today. This firm has demonstrated how IT can be a strategic tool, to the extent that it can be used for improvements in productivity through office automation.

Implementation

As has been demonstrated in this paper, IT could be used by construction enterprises as a strategic weapon to gain market niche and competitive edge. It could also be used at a national level to improve the competitiveness of the construction industry. The deployment of this strategic weapon is not without problems both at the enterprise and at the industry levels. Enterprise level obstacles may be easier to overcome, but it is well known that the construction industry - largely due to its fragmented nature - does not readily accept changes, even for the better. In an industry where many organisations participate in the construction process, organisational changes alone will not be enough to make full use of IT throughout the industry. These obstacles must be borne in mind by those working towards CIC. It is not sufficient to only address the technological and classification issues in these circumstances.

Some of the important benefits, as discussed, can only be gained when project information (say in the form of drawings in a CAD file) can be exchanged among collaborating practitioners, between government agencies and practitioners, and used during on-site operations and finally utilised in the management of the completed facility. This simple step would take a long time as it would require many changes at enterprise and industry levels. Similarly, for on-site construction, much coordination among participating sub-contractors, architects, and the main contractor will be required to facilitate the effective use of IT such as in the form of Project Management systems. For the total project information system to evolve to the stage where it can be handed down to maintenance and facility managers of the built-form, all participating designers and builders must accept the use of information through IT media. The government agencies in their role as regulators and controllers must also accept these changes. They have to go a step further, when the IT network has been implemented, to bring in legislation to force some of the defaulting practitioners into accepting these changes since one broken link can put the entire process into jeopardy.

The implications of such a scenario in which all participating practitioners are sharing the same information system are far reaching. Changes made by anyone must be so recorded for professional liability. Some aspects will have to be protected so that no changes can be made to system files. The participants who would work on the system in the early stages - the architects - would demand remuneration for their work in the initial input. Thus a new code of professional ethics and fees will have to be developed and may eventually emerge.

The professionals also need to collaborate at institutional levels to standardise computer hardware, software and information classification systems. Currently there are serious problems of compatibility. Although technically a drawing file can be converted from one system to another, with a wider IT network linking all enterprises and government agencies, to exchange all useful design information, and not just drawing files, system compatibility is the only sensible answer to growing problems. Thus the professional bodies need to take a serious view of this situation, if this is not to get out of hand, and talk to one another now to prepare themselves for the future. So far they, and other construction organisations, seem to independently express their own needs for IT. Such incremental steps will not move them beyond minor productivity gains into gaining strategic advantage from IT.

Conclusion

The manufacturing industry has received a tremendous boost in producing better and cheaper products with the help of IT. This has been possible because the manufacturing process - from design to assembly in the factory - can be integrated and coordinated through IT. This integration and coordination will not be easy in the fragmented construction industry, and will raise many technical, ethical and legal problems. The challenge for the construction industry is to pull itself together and strive to overcome these problems. IT is an opportunity for the industry to combine resources once and for all, for the industry's benefit, productivity and effectiveness. Should this not happen, the industry would be following age-old practices in the 21st century except doing them faster, but not necessarily better. The speed may save some dollars but the benefits of a better built-environment for the user, and one that is easier and cheaper to maintain may never be achieved. The construction industry must exploit this potential IT advantage.

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