32 IT INNOVATION WITHIN THE CONSTRUCTION ORGANISATION

Jennifer Whyte[1] Dino Bouchlaghem[2]

[1] Programme on Innovation in the Built Environment, SPRU – Science and Technology Policy Research, University of Sussex, Brighton, BN1 9RF. J.K.Whyte@sussex.ac.uk

[2] Department of Civil and Building Engineering, Loughborough University, Loughborough, LE11 3TU. N.M.Bouchlaghem@lboro.ac.uk

Abstract

Whilst sophisticated IT systems are being investigated and evaluated by academics, many construction organisations are still failing to implement and use IT to their strategic advantage. To address this, organisational rather than technical issues are the focus of this paper. The process by which emerging technologies can be introduced into construction organisations is explored.

The case study method was used to study IT implementation within a major house-building company. The company studied set out to introduce a virtual reality system. This was to be used for internal design review by inter-disciplinary teams within the company's regional offices. In this paper system development and implementation within the organisation are described.

The findings provide insight into the process of change, the constraints that inhibit IT implementation and the relationship between new technology and work organisation within construction organisations. They suggest that (1) user-developer communication may be critical for the successful implementation of non-diffused innovations in the construction industry and (2) successful uptake of IT requires both strategic decision-making by top management and decision-making by technical managers.

Keywords: *innovation, implementation, emerging technologies, virtual reality, organisation.*

INTRODUCTION

Whilst sophisticated IT systems are being prototyped in universities, many construction organisations are still failing to implement and use IT to their strategic advantage. To address this, organisational issues relating to the introduction of emerging technologies into construction organisations need to be considered.

Our work has focused on the use of virtual reality (VR). This is an emerging technology that enables interactive real-time viewing of three-dimensional data. Though researchers have demonstrated the benefits of using VR as an architectural design tool (Kurmann et al, 1997; Chapin et al, 1994; Funkhouser et al, 1996), recent surveys show that the technology still has few users within the construction industry (Bouchlaghem et al, 1996; Whyte et al, 1999).

Virtual reality can be considered as an innovation in the group of architectural design tools. This group includes computer-aided design (CAD) tools, which provide a more basic ability to model and visualise design. Three reasons for our interest in VR implementation are the same as reasons given by Schaffitzel and Kersten (1985) for interest in CAD implementation in the late 1980s, namely:

1. Many systems are still at the development stage and their installation can therefore be regarded as a pilot project being used partly to develop and perfect the software;
2. The technology can not be introduced in the form of 'turnkey' systems in the strict sense and substantial effort is needed to complete the software through adjustment-development measures; and
3. Introduction also requires redesigning the organisational context.

Organisational, rather than technical, issues are the focus of this paper. First the theoretical debates related to IT innovation in construction organisation are reviewed. This is done in two sections looking at (1) the specific characteristics of innovation within the construction organisation and (2) IT innovation within organisations. In the latter section we will make particular reference to the early introduction of CAD tools.

The case study of virtual reality implementation in a major house-building company will then be introduced. The company studied wanted to use virtual reality for internal design review by inter-disciplinary teams within its regional offices. The system development and implementation will be described and compared with early CAD implementation.

INNOVATION IN CONSTRUCTION

There is growing interest in the role of innovation within the construction industry and this has been the focus of research (eg. Gann, 2000; Slaughter, 1998; Emmitt, 1997). Compared with other industries, there are constraints placed on innovation within construction because of the characteristics of the industry. These include:

- The unusual extent to which the construction industry is regulated. Government regulation often has a greater influence on practice than customer preferences (Gann, 2000; Pries & Janszen, 1995).

- The adversarial culture and fragmentation of the different participants in most construction projects (Egan, 1998; Barlow & Lowenberg, 1999).
- The project based nature of construction. Projects are discontinuous and temporary and there are often poor linkages between project and business processes. This project based nature creates problems for rapid assimilation of new ideas within construction firms (Gann & Salter, 2000).
- The 'engineer's paradigm'. This is an emphasis on the short-term (project) management rather than wider issues of business management, resulting from the fact that management usually originate from practice (Pries & Janszen, 1995). Hence, within construction, undertaking research or invention outside projects is unusual (Tatum, 1987).

These particularities led Emmitt (1997) to report that though diffusion theory (Rogers, 1995) could be applied to the construction industry, modifications to the theory were necessary because of the complex nature of construction processes. As the industry is changing, it is argued that companies in the construction industry will have to operate in a more extrovert and market-driven way and they will have to reconsider their capabilities (Pries & Janszen, 1995). Gann (2000) notes that innovation occurs within the supply-chain and users play a part in stimulating and directing its course.

IT INNOVATION

The introduction of emerging IT systems into organisations may be different from other types of innovation such as the introduction of new processes or products. Within the house-building and construction industry, IT innovation has rarely been empirically studied and theorised in its organisational context, though there have been benchmarking projects (eg. Smith, *et al.* 1997); frameworks to measure benefits (Andresen, et al. 2000; Ramcharan, 1997). This section draws upon the wider literature on IT innovation, and in particular on early CAD implementation.

In the management literature, transformation of IT from a resource, which is available to all firms in an open market, to an organisation's core capability, with potential for competitive advantage, is seen as a path-dependent learning process (Andreu & Ciborra, 1996). Thus attainment of sustained IT based competitive advantage may be more a process of building organisational infrastructure in order to enable innovative action strategies rather than being first on the scene (Peppard & Ward, 1999). A classic example of the growing strategic use of the information provided by IT systems is the introduction of a ticketing system into the airline industry (Monteiro & MacDonald, 1996). The text-based information system not only allowed the ticketing to be done more efficiently, but also allowed more strategic use of information to segment markets, differentiate services and maximise yields.

The literature on introduction of early CAD systems shows that implementation often took longer than anticipated (Schaffitzel & Kersten, 1985). Implementation was lead by technical staff at middle-management level, and often through newly created positions or departments (Currle, 1989). The technical managers that lead the implementation shouldered responsibility for it, and implementation was hampered by insufficient user-developer interaction (Schaffitzel & Kersten, 1985), and a mismatch between the investment in CAD and broader corporate strategy (Currie, 1989; Forslin et al, 1989).

CASE STUDY

This case study considers the implementation of VR within a house building company. The company studied is one of the top twenty housebuilders in the UK, selling over 2,000 houses in 1998. The case study is focussed on the development, and then the implementation, of a VR package, within a regional office, and then the spread of its use to other regional offices of the group's house building operation, in the period between November 1997 and December 1999. Semi-structured interviews have been conducted with the group CAD manager, who is based in a regional office, and with the CAD managers of the two other regional offices that have sought to implement VR at this stage.

DEVELOPMENT OF THE SOFTWARE

Initial Idea

The group chief executive (CEO) started the company thinking about virtual reality. He saw presentations of 3D Studio work on video that had been prepared by the group's subsidiary construction company for sales and marketing purposes. He was impressed, but wanted more navigational control and a greater degree of interactivity. Because the animation was pre-defined, it was not possible to stop, turn, focus in on details or interact with the information in real-time, although this was already possible in the his son's computer games. The CEO thought that these functions would be useful to the company to allow them to use the computer model to spot design problems before they got to site. He questioned established methods, first praising the work that had been done, but highlighting problems to be overcome and suggesting a way to overcome them, through the use of VR.

The primary reason for developing and using a VR system in the company was design, the co-ordination of the design process and in-house collaboration. The company objectives for using the VR system were to address design issues, and to include non-technical staff in discussion about design development.

Feasibility Study and Software Development

The subsidiary construction company's IT manager assessed many different VR packages to determine their suitability to fulfil the design tasks required by the company. A particular package was chosen because it had been used to develop VR applications for use in the design process as well as in sales and marketing. The VR package chosen was a development environment for high-performance real-time graphic applications, providing a function library and productivity tools that allow a programmer to put together a VR application.

After the VR appraisal and package choice, the group CAD manager, who was then the CAD manager in one of the regional offices, became involved in the project. In this paper we describe him as the 'implementer'. In late 1997 he began negotiations with a software company to jointly develop a suitable application for site layout design. The implementer tried to create a mutually beneficial arrangement with the software company. The house-building company did not buy the exclusive right to the software but anticipated competitive advantage from the shortened lead-time and hoped to have the system fully working within the organisation before its competitors.

Software development took longer than initially anticipated and it was nearly a year before a working version of the software was delivered. The housebuilding company requirements were outlined in a document given to the software company at the beginning of the software development phase. In retrospect, the implementer felt that more precision in the brief would have reduced misunderstandings at later stages. He also felt that the software company agreed to all requests put by the house builder, as they were anxious to get the contract, but couldn't achieve all of those due to both technical limitations of VR and changes in their own operational circumstances.

Commissioning the software was difficult for the housebuilding company. The emerging nature of virtual reality meant that it had some weaknesses compared with more established technologies such as CAD. Unanticipated technical problems arose regarding the format and translation of geometric data. However despite these problems, the resultant software (*Visual Designer*) provided most of the characteristics requested by the company. It was the diffusion of the VR software within the company and its integration into the business that were seen as the most difficult processes.

IMPLEMENTATION PROCEDURE WITHIN THE COMPANY

Implementation Strategy

The regional offices of the housing developer are mainly concerned with the site layout of housing schemes. Standard housetypes are designed in head office and the regional offices use these, deciding the appropriate mix of housetypes for specific sites within their region, and creating variants and non-standards with regard to local market requirements and the input of planning authorities. The *Visual Designer* software was designed to be used to allow different professionals within the regional offices to assess the quality of site layouts. It was intended that a library of VR models of standard house-types would be built up, to allow the CAD managers in the regional offices to rapidly create site layouts in virtual reality.

Virtual reality was first implemented in the regional office which initiated the software development, then after the CAD Manager in this regional office (the implementer) was promoted to Group CAD Manager, the scope of the project widened. At the beginning of this case study, in November 1998, it was the intention for VR to be implemented in all of the regional offices of the house building operation.

The three regions studied in this case study are the regions in which the use of VR was sought at this time. It was hoped that once VR was successfully being used in these regions, the other regions would also invest in the software. Whilst region A had the *Visual Designer* software since October 1998, the software arrived in region B in January 1999. It was not introduced into region C, within the life of the case study. Additional software packages required for the use of VR were the *Visual Designer* package, and the 3D Studio for model building. The hardware used in both region A and region B was a 256 MB RAM Pentium II 333MHz with a Diamond Fire Open GL 4000 graphics card.

The CAD managers felt that the relevance of VR skills to future business operation was an important reason for investment in VR technologies. They hoped that the company would have in-house expertise in 3D visualisation techniques, to give them a strategic advantage over their competitors when 3D visualisation and VR techniques become more widespread. Many years previously the implementer had experienced the adoption and use of an early CAD package in an engineering company where he was a junior member of staff. He felt that although the early use of VR may be similarly difficult, it may offer similar improvements in the long term.

Implementation on Housing Schemes in the Regions

The implementation of the VR package was closely linked to the projects (housebuilding schemes) that it was initially used on. Individual regional CAD managers have had to find funds and justify the implementation of the software in their regions, as the purchase of the software, which was not centrally funded, could only be justified in terms of its benefits brought to these projects.

In all of the regions, there was a degree of uncertainty about which projects would use VR. It was explained that this was due to the nature of house building, as there was a high drop out rate for sites. As a company if they "*look at a hundred sites in a year, [they] might get only ten...*" It was felt that this was something that had to be taken into account when considering the use of the package in the design process. Some schemes that were due to be put into VR, were radically altered after discussion with planners, or were left due to commercial reasons.

Regional CAD managers had to put forward a case to their regional directors and then to the IT department in central office to mitigate fears that the software would not be used, but this process resulted in a concentration on short-term benefits of the VR package. During the case study period, there was a tendency to delay the use of VR on a scheme until the layout was nearly finalised. This was in order to reduce abortive work, and to produce a VR model that is of sufficient quality to impress other professionals within the regional office with the potential of using VR. CAD managers expressed concerns that the package would increase their workload in the short term, as they bear the burden of responsibility for the successful use of VR on the initial house building scheme, on top of their other responsibilities and without additional resources.

Region A: Established Use

The VR package was first piloted in region A, where the Group CAD Manager was based. Several schemes were modelled and visualised within the *Visual Designer* package during the first year of its use. The first housing scheme to be put into VR was produced by the software company that developed the application, to demonstrate the software capabilities. Six standard house-types were modelled in 3D Studio and used in the model. The model covered thirty-six units on a scheme consisted of a total of 200 units. This model was later shown to the CAD managers in other regional offices to encourage them to invest in the software. Another housing scheme, which consisted of the six standard units modelled as part of the development process was then chosen to be put into VR. The reason for this choice was to allow the first model to be built in-house to be created with relatively little modelling work. Models were created for a further scheme, though this *"dropped out of the picture for a while but has come back in again for a number of different commercial reasons*." A 3D Studio model of the mews house was also

produced, and at the time of the interview with the CAD manager, a block of flats was in the process of being modelled. The manager expected it to take approximately a week to finish the modelling work. The reasons given for the time consuming nature of the modelling process were; the initial time required for learning the use of the software, when the user was at the bottom of the learning curve; and involvement of those staff in other projects.

Region B: Scheme Sought

Although this VR software was not specifically designed for presentations, a director wanted to use the VR system for on-site presentation to clients in the show house. The software was purchased for region B in January 1999, however difficulties were encountered in finding a suitable scheme as a showcase to demonstrate the use of VR to the region. The CAD manager had limited time to dedicate to learning the package due to the pressures of other work and staff shortages within the region. He did not produce a model of a housing scheme, as a decision regarding the choice of scheme had not been reached. One site, which was being considered for VR trial in January 1999 did not progress beyond the feasibility stage. Another larger site, on the grounds of an old hospital, was under consideration in June 1999 but had still not been put into VR by November 1999. This large project was zoned into different sites, and the first site was expected to be put into VR in the early part of 2000. Work on the VR model was delayed, to avoid abortive modelling work, as the site layout underwent major changes after a meeting with the planners.

Region C: Model Demonstrated

At the time of the first interview, two projects were under consideration for piloting VR in the region. One of these, was a large brown field development that was quite different from the normal developments, and the other was a small laundry site. At the time of the second interview, the VR package had been used on a small development of 6 houses. Though the site is small, each unit was of very high value and the development was contentions in terms of planning permission, the land director initiated the project with regional CAD manager. The VR package was not used within the region for the creation of the model, but region A and the sister construction company were contracted to carry out this work. More detailed models of housetypes were created to counter earlier criticism of models produced in region A, that the models were too simple. The VR model was then shown to a group of about 12 people. These people were non-technical employees within the region. The software gave a good impression of the site and highlighted some previously unnoticed design problems at a stage that they were easy to overcome. For example, from the entrance of one of the houses, three triple garages were visible opposite. They weren't all in a row, and were staggered but the view of nine garage doors that belong to other plots was felt to be unacceptable. This was something that no one had spotted before, but having looked at the model this point was noticed. At the stage that the model was being used the problem was easy to resolve by changing the orientation of the garages. The use of multimedia techniques was useful during this demonstration and the 3D Studio model was deemed to be impressive. However visualisation of detailed housetypes led to a time lag and unacceptably slow frame rates.

ISSUES ARISING FROM THE IMPLEMENTATION PROCESS

Within the regions, pressures of other work limited the time available to CAD managers wanting to learn to use the *Visual Designer* software. There was no manual for the software, (although there was an expectation that the implementer would write rough guidelines for users within the company). As well as learning the *Visual Designer* software, the CAD managers had to consolidate their knowledge of the modelling package 3D Studio, which was to be in the VR model creation process. The CAD managers had been provided with some formal training in 3D Studio but had not previously used the package as a part of their job. They found it difficult to budget time for VR modelling due to heavy workloads and tight deadlines, which were exasperated by staff shortages in some of the regions.

The CAD managers saw the period in which this case study was conducted as a testing phase for the software. However, although it was expected that there would be some unforeseen technical problems to be overcome, the availability of funds for continual development was not apparent. It was unclear how a database of housetypes was to be generated and maintained. It was not determined whether the regions would agree funds for its creation centrally (or externally), whether CAD managers would be given time to produce models, or whether the creation of 3D housetype models could be part of the housetype design process in central office.

FUTURE DIRECTIONS

In the summer of 1999, the group CAD manager (implementer) became the group design systems manager. He became involved in a project to set up a web-server for use on some of the company's larger projects. Following the example of some other large construction companies, this web based type environment was set up to allow all participants remote access to relevant design information held on a server, dependant on the security notification of the user. This design portfolio is intended to allow the house building organisation to share all the design information from the regions and the head office. The CAD manager from head office manages this system, which began running in November 1999. Before implementation the group CAD manager tried to consult with other construction companies about their experience of using such systems. Though a number of different software architectures were investigated, a system was chosen for its maturity, and for the personal contact with and access to the software developer built up through previous information gathering exercises and networking related to the VR project.

At present of the use *Visual Designer* software has taken a back seat. However the design portfolio software used to share data via a web server is capable of importing the Virtual Reality Modelling Language (VRML) file format, providing an opportunity to use it in a distributed manner and assess virtual models of housetypes and site layouts, as well as working drawings. The group design systems manager believes that the design systems they are using at present are not sophisticated enough to present the quality of schemes that are being produced. At present the visualisation tools they are using are used in an ad hoc manner and they want a more considered approach.

DISCUSSION

This case study explored many aspects of the processes of change, the constraints that inhibit IT implementation and the relationship between new technology and work organisation within construction organisations. Many of the findings in the literature on innovation in construction organisations, and IT innovation in general were supported by the results of the case study. In particular there are striking parallels between the empirical data on VR implementation presented here, and previous research on the early implementation of CAD in organisations.

In a manner similar to that found by Currie (1989) in CAD research, it has been the middle management that have been responsible for achieving the benefits from the technological change. Although the initial incentive for introducing VR was the interest expressed by the Chief Executive, there has been a lack of direct involvement by board-level management in the development and implementation of the *Visual Designer* software. This has resulted in implementation problems, including a lack of co-ordination between different parts of the organisation, a concentration on short term rather than longer-term benefits, and the lack of a project specific budget in terms of both time and money.

The introduction of VR within existing processes imposed an additional burden on CAD managers, who were learning and using the new software on top of their routine operations. There was no specific budget for VR development and software purchases were made out of regional budgets and justified in terms of the projects they were initially used on. Introduction of the software into the regions was also slow, as it was dependent on agreement in many sections of the company and approval of a scheme that the software could be used on.

The implementation of VR has been effected through newly created positions. Most notable has been the change in the role of the implementer, who started out as a regional CAD manager, then moved into the newly created position of group CAD manager, and finally had that redefined to the newly created position of group design systems manager. This implies that these technologies are creating (at least initially) an increasing specialisation of roles within the company.

The lack of collaboration between the software developer and the house-building company had a negative impact on the success of the implementation, in a similar manner to that described in the literature on early CAD implementation. This was despite the initial agreement, which was allowed the software company to commercialise the end product developed, potentially selling it to rivals of the house-building company. The software company did not take this opportunity and relations between the software company and the house-building company ceased.

CONCLUSION

This paper has considered the use of emerging technologies within construction organisations. The characteristics of the case study of IT implementation described above suggest that:

1. user-developer communication may be critical for the successful implementation of non-diffused innovations in the construction industry. In the case study the failure to maintain relationships with the software developer throughout the implementation process led to many problems with the IT remaining unresolved.

2. successful uptake of IT requires both strategic decision-making by top management and decision-making by technical managers. A forum between top management and the middle level technical management would allow innovation to be co-ordinated at both the project and the business level. Middle management have the technical expertise and vision to implement emerging technologies but key strategic decisions need to be made by top management and it is at the top management level that the project must be championed within the company.

This case study has described early virtual reality introduction within construction. There is a need for further research to compare and contrast the introduction of different types of IT innovations within construction organisations. This research should draw upon the literature on both innovation in construction, and IT innovation, as well as empirical evidence. Such research would enable us to better characterise and explain the particular characteristics of IT innovation within construction companies, and thus to explore how this process of implementation can be improved.

REFERENCES

Andresen, J., Baldwin, A., Betts, M., Carter, C., Hamilton, A., Stokes, E. and Thorpe, T. (2000) A Framework for Measuring IT Innovation Benefits, *Electronic Journal of Information Technology in Construction*, Vol. 4. http://www.itcon.org/2000/4/paper.htm

Andreu, R. and Ciborra, C. (1996) Organisational Learning and Core Capability Development: the role of IT, *Journal of Strategic Information Systems*, Vol. 5, pp. 111-127.

Barlow, J. and Lowenberg, P. (1999) *Bringing construction industry partnering to the regulated sector. The case of the United Kingdom*, A report for Windborne International. Brighton: SPRU, 41p.

Bouchlaghem, N. M., and Liyanage, I. G. (1996) Virtual Reality Applications in the UK's Construction Industry, *Construction on the Information Highway*, CIB W78 Working Commission on Information Technology in Construction, Bled (Slovenia), Turk, Z. (Ed), University of Ljublajana.

Chapin, W.L., Lacey, T.A. and Leifer, L. (1994) *DesignSpace: a Manual Interaction Environment, of Computer Aided Design,* Human Factors In Computing Systems, the CHI'94 Conference Proceedings, Boston, MA, 24-28 April.

Currie, W.L. (1989) Investing in CAD: a case study in ad hoc decision making, *Long Range Planning*, Vol. 22, no. 6, pp. 85-91.

Egan, J. (1998) *Rethinking Construction*, the report of the Construction Task Force to the Deputy Prime Minister, John Prescott, on the scope for improving the quality and efficiency of UK construction, London: Department of the Environment, Transport and the Regions.

Emmitt, S. (1997) *Diffusion of Innovation in the Building Industry*, PhD Thesis, Manchester University.

Forslin, J. Thulestedt, B-M, and Andersson, S. (1989) Computer-Aided Design: a case of strategy in implementing a new technology, *IEEE Transactions on Engineering Management, special issue on the Social and Organisational Dimensions of Computer-Aided Design*, Vol. 36, no. 3.

Funkhouser, T., Teller, S.J., Sequin, C.H., and Khorramabadi, D. (1996) The UC Berkeley System for Interactive Visualisation of Large Architectural Models, PRESENCE: Teleoperators and Virtual Environments, Vol 5, No 1, pp 13-44.

Gann, D. (2000) *Building Innovation: Complex Constructs in a Changing World*, London: Thomas Telford.

Gann, D. and Salter, A. (2000) Innovation in Project-Based, Service-Enhanced Firms: the construction of complex products and services, *Research Policy*, Vol. 29, pp. 955-972.

Kurmann, D., Elte, N. and Engeli, M. (1997) Real-Time Modeling with Architectural Space, *Proceedings of CAAD Futures*, Munich, 4-6 August, pp 809-820.

Monteiro, L. and Macdonald, (1996) From Efficiency to Flexibility: the strategic use of information in the airline industry, *Journal of Strategic Information Systems*, Vol. 5, pp. 169-188.

Peppard, J. and Ward, J. (1999) 'Mind the Gap': diagnosing the relationship between the IT organisation and the rest of the business, *Journal of Strategic Management Systems*, Vol. 8, pp 26-60.

Pries, F. and Janszen, F. (1995) Innovation in the Construction Industry, the dominant role of the environment, Construction Management and Economics, Vol. 13, no. 1, pp43-51.

Ramcharan, R.S. (1997) *Strategic Impact of Innovations in Information Technology in Constructio*n, Ph.D. Thesis, MIT, Mass.
http://theses.mit.edu/Dienst/UI/2.0/Describe/0018.mit.theses/1997-267

Rogers, E.M. (1995) *Diffusion of Innovation* (4th Edition), New York: The Free Press.
Schaffitzel, W., Kersten, U. (1985) Introducing CAD systems. Problems and the role of user-developer communication in their solution, *Behaviour and Information Technology*, Vol. 4, No. 1, pp 47-61.

Slaughter, S. (1998) Models of Construction Innovation, *Journal of Construction Engineering and Management*, May/June, pp. 226-231.

Smith, D., Atkin, B., Clark, A. and Betts, M.(1997) The Experience of Benchmarking Construction Information Technology, *Global Construction IT Futures*, 16-19 April, Salford, UK.

Tatum, C.B. (1987) Process of Innovation in Construction Firms, *Journal of Construction Engineering and Management*, Vol 113, no. 4, pp. 648-663.
Whyte, J., Bouchlaghem, N., Thorpe, A., and McCaffer, R. (1999) A Survey of CAD and Virtual Reality within the House Building Industry, *Engineering, Construction and Architectural Management*, Vol 6. No. 4.

Zuboff, S. (1985) In the Age of the Smart Machine: The Future of Work and Power, New York: Basic Books.