nD ENABLED CONSTRUCTION – HOW DO WE GET THERE FROM HERE?

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ABSTRACT: The processes which traditionally characterise the design and construction industry are incremental and lack effectiveness and efficiency. The *From 3D to nD Modelling* project is developing an ICT-based building information model to facilitate improved communication and holistic decision-making amongst the multi-disciplinary professionals involved. The nD tool is designed to allow concurrent design changes by all the stakeholders and practitioners involved in the building's lifecycle – from client requirements, design, construction and maintenance. Whilst the workshops held to date have demonstrated both academic and industrial support for the model and its theoretical approaches, some of the identified barriers to implementation may mean slower uptake by the industry than may be desirable, based on the expected benefits. These barriers are predominantly cultural and social in nature, but also involve technical standards and the integration and inter-operability of these. The implementation issues are discussed in light of business process re-engineering (BPR) literature in order to try to understand how the implementation process can be managed most effectively.

Keywords: BPR, culture change, information system implementation, nD modelling.

1.0 INTRODUCTION

There are many and a variety of stakeholders and professionals involved in a building's lifecycle and there are huge benefits to be gained by companies able to satisfy the stakeholders in the most efficient and effective ways possible. The University of Salford's *From 3D to nD Modelling* project has developed a vision for computer-enabled construction which aims to remove the currently inefficient and incremental ways of working which currently characterise the industry, and replace them with more holistic decision-making processes. The business case for an nD model has been demonstrated through a number of workshops with national and international academics and industrialists. These have shown the current problems within the industry and the areas of opportunities where huge benefits could be made through the implementation of an nD model and its ways of supporting working. However, despite the widespread support, if the model is not taken up and its benefits demonstrated, it is likely that it will be hailed as yet another technological fad. To date, the problematic industry issues that the project is aiming to overcome - primarily of culture - are the very same aspects that are the greatest barriers to its implementation. This paper will outline the perceived need for nD modelling and then discuss the findings of the workshops in light of literature exploring business process reengineering themes and establish ways that some of the implementation barriers may be overcome to enable a more efficient and effective construction industry.

1.1 The nD modelling approach vs. traditional construction processes

The volume, detail and technical nature of the information that is required in the whole life-cycle of a building means that specialist skills and training are needed to interact with it. For this reason, individuals or groups without specialist experience can often be omitted from decision-making e.g. in public forums for regeneration. Therefore, there is a need for data

representation to be accessible and ICTs can provide a visualisation platform which can enable better comprehension through the use of a 3D building information model. nD Modelling is aiming to go a stage further by including non-geometric information – acoustics, thermal requirements, accessibility and crime amongst others – and show the impacts that changing the design can have upon these parameters. For example, for crime purposes, it is preferable for windows to be located as high as possible above ground level and for doors not to have glass in them and for them to open outwards, design features which cause access problems for people in wheelchairs. Adopting this holistic approach can improve decision-making for professionals and it enables better comprehension by other stakeholders.

1.1.1 Holistic vs. incremental change

It is generally now accepted that the design and construction industry's sequential processes are inefficient compared to concurrent working methods in which numerous processes take place at the same time and in parallel to each other. The organisational concept of concurrent engineering aims to increase the efficiency and effectiveness of product development by integrating and making temporally parallel the product and process developments (Durst and Kabel, 2001).

> "Concurrent Engineering is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from concept through disposal, including quality, cost, schedule, and user requirements." (Winner et al, 1988, cited in CIB website)

This definition emphasises a holistic approach and the inclusion of all stakeholders and their expectations regarding the resulting product or service.

Although the nD modelling project did not consciously set out to do so, it has adopted a number of the most prominent characteristics of a concurent engineering framework:

- The interconnectedness of technical, organisational, social and personnel aspect in the CE environment (Durst & Kabel, 2001)
- The related philosophy that formerly sequential processes "can be carried out temporally parallel or overlapped, or even fully integrated i.e. summarized as one activity" (Eversheim, 1995 p2).
- The concept's aim to "include all concerned areas of the product life cycle, from conception to design, production and eventually waste disposal" (Luczak, 1998 p522)
- Pennell & Winner (1989 p648) argue the targets of CE are associated primarily with: a reduction of product development time, by simultaneously; improving the product quality and; reducing production costs.

Like nD, Durst & Kabel (2001 p169) argue these goals could be obtained by "an improved consideration of requirements between the different departments involved in the product development process." Additionally, "activities to coordinate processes and the transfer of information in the process should be started as early as possible." (Stahl et al, 1997 p380)

1.1.2 A multi-dimensional, inter-disciplinary approach vs. 1-dimensional collaborating experts

'E-science' has been defined through its purpose to achieve "world beating science through the effective use of the latest information technologies" by conducting research that crosses disciplines and is located at "the intersection of many scientific disciplines" and which

consequently will "change the dynamic of the way science is undertaken" (Boyd 2001). E-science is one example of what Gibbons et al (1994) have identified as a trend towards the 'new' or 'mode 2' production of knowledge, identified as a method of collaborative working which requires ICT infrastructure such as e-mail, video-conferencing and the internet to connect and facilitate working between individuals who are spatially distributed across time and space. As a result of knowledge sharing, the web of communication networks between the discrete sites of knowledge production become denser and the knowledge produced increases and varies in terms of volume and type as it is re-configured for new and different purposes.

Gibbons et al (1994) distinguish between mode 1 knowledge production – knowledge that furthers the advancement of the subject as a pure and one dimensional discipline – and mode 2 knowledge that has wider applicability and relevance to more subject areas: it is comprised of a number of disciplines; is produced in the context of application (as opposed to problem solving using purely the practices typical to that one discipline); is knowledge that is socially accountable and heterogeneous in terms of the organisational diversity of skills and experiences brought to it; and it is trans-disciplinary. Importantly, it is of no relevance whether the knowledge itself is absolutely new or not; its newness resides in the new contexts in which it is applied and then re-configured for problem solving purposes.

Produced in this way, Nowotny et al (2001) observed that these processes resulted in knowledge that increasingly transcends the discipline boundaries traditionally drawn by academic disciplines, departments and professional bodies. The terms multi- and inter-disciplinary are often used in a general sense to describe any collaboration that takes place within mixed discipline groups. The distinction between the two can be demonstrated by the extent to which the collaborators work within their own discipline defined boundaries, or develop a new shared perspective that transcends all the boundaries which comprise it, and from which it is impossible to break down into its constituent parts.

1.3 Organisational change

Moreton & Chester (1997, p2) argue that the desire to make fundamental, organisational changes via business process reengineering (BPR) is driven by three aims, to:

1. develop inbuilt capability to detect and respond to changing circumstances
2. gain immediate, direct economic benefits, mainly as a result of higher levels of customer satisfaction and streamlined operations
3. achieve positive employee benefits, e.g. increased job satisfaction and personal development, which contribute to the other two aims

They define transformation as "a change from a functional organisation of the business to one that is centred on the main business processes", processes being a set of activities which collectively add value to the customer. The emphasis upon making a large and significant as opposed to incremental change is emphasised by Adams (1984) who describes organisational transformation as "profound, fundamental changes in thought and actions, which create an irreversible discontinuity in the experience of a system." The lack of flexibility of the traditional Taylor-inspired organisational model has seen its replacement with more organic models: there is less focus upon internal efficiency and more upon external requirements and so the organisation's successful operation and survival is based upon a wider repertoire of capabilities able to exploit total organisational capability in the longer term rather than limited responses to short term pressures.

Galbraith (1977) argues that as a goal becomes more diverse or changes in nature, as task performance becomes more demanding or as the task is split between more people, the

information needed to carry out any task increases. Working in a stable environment on a well understood task involves much advance planning, but as uncertainty increases, the amount of information communicated and processed during decision-making also increases.

1.3.1 The change process

Researchers agree that process transformation should follow a framework or structure: Davenport & Short (1990) identified 5 steps in process re-design, most of which companies succeeding with BPR were following. Moreton & Chester (1997) identify 3 steps – 'establish the context' (creation of a new vision and gaining commitment to it), 'transition' (including detailed design of the new organisation and its systems, both manual and technological, and associated development activities) and 'exploitation.' But for the three transformation results above to be achieved, three components must be present:

- The alignment of business, organisation and systems strategies. Without this, effort is misdirected leading to ineffectiveness;
- Commitment to sponsors, employees and others in decision-making. This allows full exploitation in the organisation and systems;
- Competence in appropriate managerial and operational skills and expertise. Without these the organisation and systems will be ineffective.

1.3.2 What IT can enable

The debates about how computers change our lives continue unabated today: the visionaries believe an information revolution is now in our midst whereby new opportunities, enabled by emerging technologies such as artificial intelligence, virtual reality and hypermedia, will allow innovative practical and intellectual developments. In evaluating this IT-job impact and seeking to establish the processes by which benefits or problems may emerge, two main theories have emerged:

- technical determinists, believing that technology is the single most important factor in determining an organisation's success and survival, argue that IT investment is the only way to prevent being 'left behind'
- a social action approach positions technology as an enabler and that management's strategic choices determining how technology will be used will affect the organisational structure, IT adoption being one resource of many

Moreton & Chester (1997, p9) argue that IT is probably the single most important enabler of change, but the impact of IT on business transformation depends on the extent to which it enables business processes to be changed. In discussing IT's role in BPR, Hammer and Champy (1993) go further and state that "a company that cannot change the way it thinks about information technology cannot reengineer." However, as numerous information systems are designed independently of the organisation's other functions, it is essential to coherently combine the design, development and exploitation of the systems and the organisation. Taylor & Katambwe (1988) found that power distribution determines the technology's impact upon organisational structure and practice and that the introduction of new technologies tends to support the status quo. This is because users shape technology to fit their preconceptions of organisation practice and authority hierarchies rather than the technology shaping their practices and decision-making structures.

IT can help enable the three overall change aims – vision creation, transition and exploitation – outlined above. Although information systems are often seen to be difficult to use, expensive and time-consuming, they do have the potential to support responses to change

due to the information processing, analysing and communication that they enable to detect market changes. IT can achieve immediate and direct economic benefits through enabling business process streamlining whilst allowing changes to scope and scale, and decentralisation.

Moreton and Chester (1997, p65) argue that there's general acceptance IT is moving from being a support function addressing internal efficiency, to becoming a frontline business asset. As such, it has an increasingly important role in shaping market forces, supporting services and providing new market opportunities. Systems are able to provide competitive-edge applications which provide the basis for organisational transformation and can:

- assist product and market planning and in product design
- are products/services in their own right
- help influence relationships with customers, intermediaries, suppliers and regulatory agencies
- help frustrate or pre-empt moves by existing competitors or by new entrants to the marketplace

Porter & Millar's (1985) concept describes the importance of information to a business, and there are two information types: that used in business processes, and information that is a part of the product itself. The factors which determine information intensity fall into three categories and are related to supply, internal factors and the marketplace. Based on their interviews and other supporting evidence, Porter & Millar conclude that among the pioneering businesses, there's evidence of a positive correlation between information intensity and the relative importance of information (and IT therefore) in the transformation process. As customer satisfaction is a priority for transforming businesses, Moreton & Chester (1997) argue that they are more likely therefore to enhance their products and processes in a way that increases information intensity. Therefore, assessment of a business' information intensity allows a relatively objective assessment of the importance of IT in the transformation process, and secondly, since satisfaction is an important transformation element, transforming businesses become more 'information intense' which in turn increases the importance of IT as an enabler. An organisation's ability to exploit its 'information resource' can be a vital ingredient in ensuring success; according to Cash & McLeod (1985), the difference between strategic winners and losers is that winners look for and develop new high value-added applications, while losers continue to amend and augment their obsolete low value applications.

Zuboff (1988) argued that 'information technology is characterized by a fundamental duality that has yet to be fully appreciated': technology can be applied to automate operations, replacing human effort and skill and providing more control and continuity for less cost, and it can be used to create information about the underlying processes by which an organisation accomplishes its work, 'informating' being Zuboff's term to capture aspects of using technology which may go beyond automation. Therefore, the organisational consequences of technological change will be determined by the extent to which either of the above is emphasised, this itself being dependent upon organisational strategy. The uniqueness of IT lies in its informating capacity and transformed organisations will chose to exploit this to their benefit

1.3.3 The problems of IT-enabled change

Most information systems tend to support the mechanistic organisational model and have often been designed for a particular application and as such automate internal functions and fail to take account of organisational strategy or the overall technical infrastructure. The lack

of planning means the systems then become obstacles to the system development needed to support the business effectively. The resulting lack of interoperability is a particular problem which leads to inefficiencies and lost opportunities. Pioneering businesses have found that much of their application portfolio was focused upon supporting internal administration functions, rather than providing a useful basis for a customer and business process-oriented approach which emphasises the importance of information sharing and multiple transaction processing.

Users attitudes towards, and fears of, technology, including concerns that it may make their jobs obselete, are an important factor in the success of IT-enabled change. Baraudi, Olsen & Ives (1986) have developed a statistically proven model linking user involvement in systems development to positive user satisfaction. Validated with over 200 US manufacturing organisations, they also found satisfied users make more use of their systems. But the systems have to be perceived as usable and useful and so systems designers will focus upon usability as a quality factor. This can be summed up as the time invested learning should equal the benefits obtained through using it.

2.0 RESULTS

The academic workshops were fundamental to the development of the vision and deciding where the immediate needs were for research. The national and international workshops are of more relevance to organisational change and they focused upon the practicalities of implementation as viewed by industrialists and world-leading academics. The findings of these workshops helped to develop and gain support for the vision.

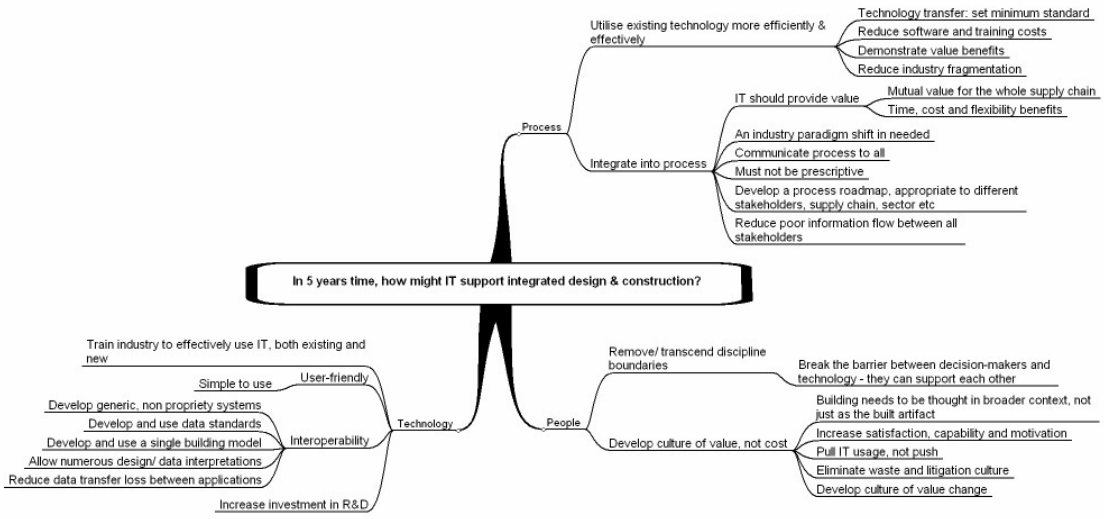

Figure 1: How IT might support integrated design in 5 years time

In keeping with the general themes of process, technology and people, the findings of the national workshop were analysed and broken down into issues of these types. With respect to the question of how IT might support integrated design and construction in 5 years time, much time was spent trying to establish where we currently are and the systems that are and should be used. As can be seen in more detail in figure 1, there was much discussion about the current problems of the industry and its structure, and trying to establish the exact starting point from which organisational change should start. This was argued as being due to the number of stakeholders involved in its processes, but also because of the fragmentation and lack of coherence of information flow and relationships.

Much discussion focused upon the systems to be used to support integrated design and it was found that already, there were industry leaders using computer modelling. However, few of these were doing this to the extent that they truly fulfilled their potential in terms of effectiveness and efficiency and this scenario was described as "…islands of automation, islands of excellence in an ocean of mediocrity." Whilst the potential benefits of ICTs were generally accepted – "…the future would be transferred through visualisation" – meeting futuristic ideas of change would have to be balanced with the practicalities of managing that change – "…IT skills are lacking and so more education and training is required."

Consideration of the longer 20 year time frame prompted more radical and less incremental change ideas. The most commonly discussed theme was that of data and information needs and the systems needed to support them, but this was tied in with a need for philosophical change. This is exemplified by the idea of *enterprise information* which is holistic and aims to handle all aspects of business. Such a system would be central to all those using it and its data would be "…accessible and editable by all on demand" and so it would be "…continually building, self-building and self-generating." Moreover it would have a level of flexibility which would make the system symbiotic with individual's working and learning styles and this would help with continual organisational learning. This change in perspective argues for a move in focus away from the nitty-gritty of technology and consideration of the system as a whole in which technology might or might not play a part. This change in technological approach is shown also by the wish for technology to provide options for more solutions allowing individuals to tailor their solutions to their own interests, rather than be channeled in the prescriptive ways in which technology has be designed up until now – see figure 2.

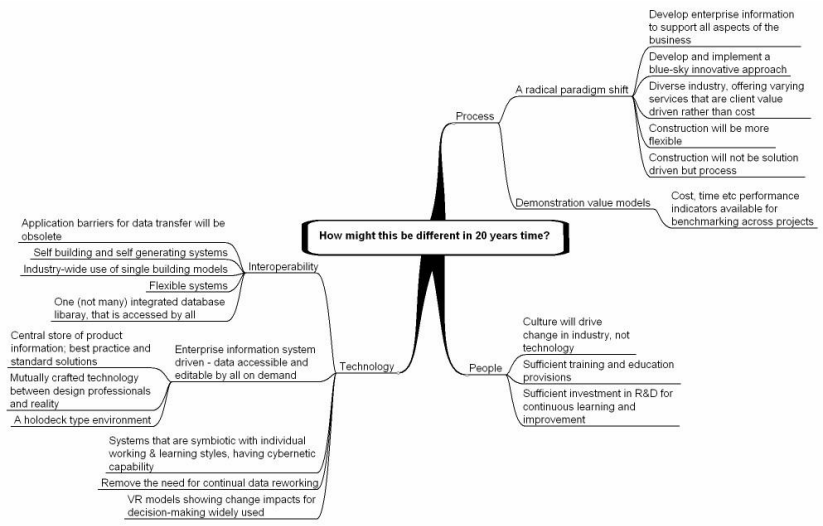

Figure 2: How this might be different in 20 years time

The final part of this workshop starts to illustrate the wider issues which will determine the success of business process change, focusing as it does upon the barriers and opportunities for implementation of nD modeling within the industry. The greatest barrier identified was deemed to be the industry's structure in general and included problems such as short-termism, lack of trust, process fragmentation and lack of stakeholder communication. Separate from these, but similar, the second greatest barrier was thought to be the current systems being used, and not just IT systems, which were seen to get in the way of effective working. Again

these findings have been broken down into people, process and technology and can be seen in figure 3.

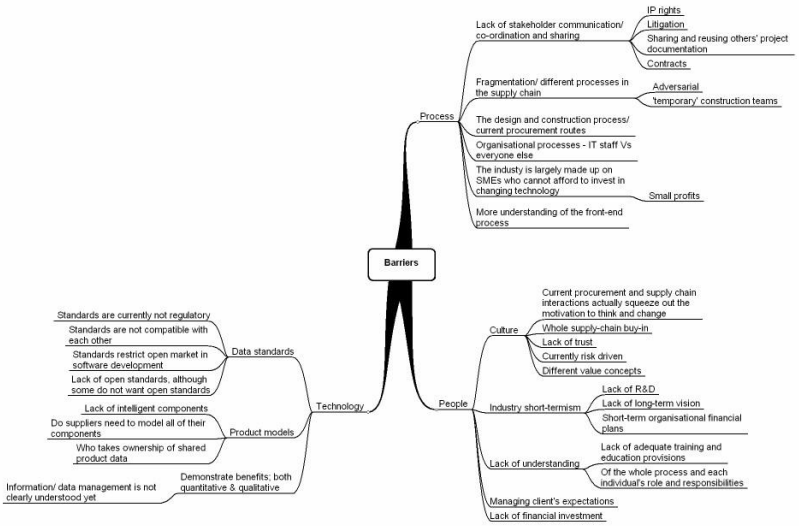

Figure 3: Barriers to nD modelling implementation

The opportunities – aside from those which would obviously be realised once the barriers named were removed – are important as they provide the drivers for change, pushing the industry towards its goals of organisational improvement. These goals have predominantly cultural benefits and were mostly identified as involving knowledge capture, utilisation and transfer which would help to develop a more open, trusting and knowledge sharing culture within the industry. This knowledge sharing would also occur between academia and industry, to help educate tomorrow's leaders. Such education and training made up the second largest grouping of perceived opportunities within both higher education, the field and through other pro-active groups and centres.

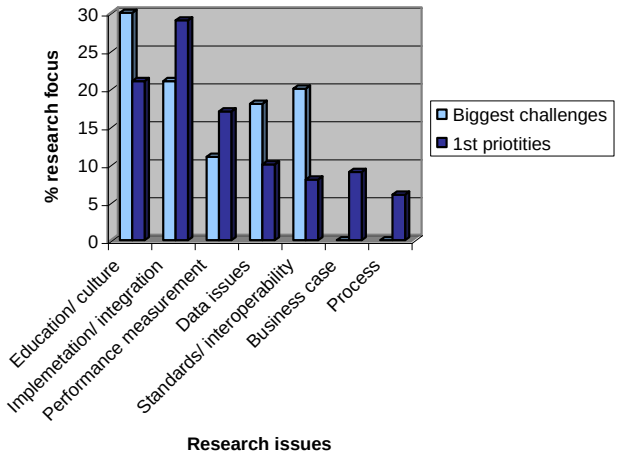

Figure 4: Bar chart of 1st priorities & biggest challenges

However, each problematic issue to be solved may not have equal importance in terms of priority, as evidenced by the international workshop. The bar chart in figure 4 shows that whilst culture, implementation and interoperability might provide the biggest challenges,

these should not necessarily be the issues upon which we should focus most of our energies as implementation, culture and then performance measurement were deemed to be the first three priorities in that order.

3.0 DISCUSSION

Ultimately, for BPR to be successful via the implementation of nD modelling, it must achieve the three aims identified by Moreton & Chester (1997 p2) of development of capability to detect and respond to change, economic benefits as a result of streamlined operations with customer satisfaction and positive employee benefits. Having a re-engineered organisation that is flexible enough to respond to change was seen to be of significant importance in the 20 year period in particular with the need being cited for 'flexible (IT) systems' and flexible processes. It has clearly been established – by nD's workshops and others – that the incremental way in which the great number of professionals work in the design and construction is wasteful and that organisational change is needed to change the processes involved to make them more efficient and provide greater value to stakeholders, and so there is a need for BPR.

As supported by the workshop findings and proposed as the approach that needs to be taken by proponents of BPR, "profound, fundamental changes in thought and actions, which create an irreversible discontinuity in the experience of a system" need to occur. This could be particularly problematic for construction because of the number of stakeholders, aspects to the building lifecycle and accompanying processes: as found in the national workshop, many delegates found it difficult to describe the current state of the industry and this inevitably raises questions as to which individual processes to improve and what the knock-on effects might be. This underlines the importance of trying to make absolute as opposed to incremental changes. The ideals of inter-disciplinary collaboration and mode 2 knowledge production also support this as a way of producing new knowledge which is fundamentally different from the constituent disciplines that have combined to find possible solutions. This implicitly argues for a change that, rather than continuing the lines of thought, sees a break based on what has gone before and thus involves thinking that is more blue sky and radical in nature.

The nD project is also pushing for more holistic decision-making and in the process of doing this, aims to broaden the thinking of stakeholders so that they become multiple dimensional thinkers rather than the one dimensional, discipline based experts that the industry currently has. This change in philosophy is also parallel to the processes which an nD model aims to support. BPR pushes for the removal of rigid efficiency models and calls for their replacement with models that are more flexible and with individuals who have a wider skills repertoire. In trying to broaden the understanding of stakeholders so that they are able to make decisions throughout the whole lifecycle, BPR and nD modelling have these aims in common with one another. This argument is supported by the national workshop finding that process integration is needed and that in the short term information flow should be improved and a shift in paradigm is needed with this needing to be more radical in the longer term.

It is explicit in Hammer & Champy's (1993) discussion on BPR that IT must be involved in the change process. At first this deterministic viewpoint on IT would seem to go against the general views on IT held by the workshop participants, which favours a more supportive role for IT. However, Hammer & Champy, like the workshop participants, argue that IT should not be implemented to bring about changes in processes, rather the IT should support the process changes that are made. This minor but significant distinction might go some way

to explain Taylor and Katambwe's (1988) finding that IT's impact upon organisational structure when introduced tends to support the status quo. This view can be corroborated by the workshop finding that systems and IT systems sometimes get in the way of effective working, something which should be expected if IT is applied to support the wrong organisational processes. This may also explain why it is that companies that have already implemented nD-type models have failed to see the maximum benefits that could be expected.

One of the tasks which nD modelling should be able to have a significant impact upon is information management. This is born out by Gael's (1977) argument that information requirements grow and become more complicated if a large number of people are involved in a task or if the task changes. This situation is especially true of construction in the absolute first instance, given the number of stakeholders and the amounts of information involved. Data issues were seen to present quite a large challenge in the international workshop, perhaps for this reason. Moreton & Chester (1997) found that information intensity of the business affected senior management's views on the contribution IT might make to change and the greater the intensity of information, the greater importance of IT. This finding is important as it highlights the role information can play in adding value to its organisation, both internally for its employees and externally to deliver value to stakeholders. In fact, Cash and McLeod (1985) found that the difference between strategic winners and losers was the extent to which new high value-added applications were developed to exploit the information resource as opposed to making amendments to their existing and obselete systems. Again, this emphasises the importance of new developments rather than incremental improvements to existing structures. The importance of the role of IT was seen most clearly in the national workshop 20 year timeframe which emphasised enterprise information which is of relevance to all aspects of business and life.

4.0 CONCLUSIONS

This paper aimed to highlight some of the issues and benefits of business process reengineering (BPR) and establish whether these could provide some insights into the feasibility of using nD Modelling to reengineer the design and construction industry. In terms of approach, the nD Modelling project and BPR have some common themes, most significantly the need to take a holistic approach to thinking and working which requires aligning all of the processes and strategies (IT, business processes, and organisation), the requirement of having an absolutely new approach as opposed to making incremental changes and finally the application of IT to support the new processes. Probably the major problem for the industry at the moment is its culture which has resulted in limited success with information system implementations and which actually gets in the way of more effective and efficient working and with added value for stakeholders. To date, there has been wide support for nD Modelling and its vision for the future of construction from academics and industrialists throughout the world and this will be an essential asset to help drive the vision forwards to successful implemntation

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