Theme:

Title: **Developing a vision for an nD modelling tool**

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Abstract: *The design of a building is a complicated process, having to formulate diverse components through unique tasks involving different personalities and organisations in order to satisfy multi-faceted client requirements. To do this successfully, the project team must encapsulate an integrated design that accommodates various social, economic and legislative factors. Therefore, in this era of increasing global competition integrated design has been increasingly recognised as a solution to deliver value to clients.*

The 'From 3D to nD modelling' project at the University of Salford aims to support integrated design; to enable and equip the design and construction industry with a tool that allows users to create, share, contemplate and apply knowledge from multiple perspectives of user requirements (accessibility, maintainability, sustainability, acoustics, crime, energy simulation, scheduling, costing etc.). Thus taking the concept of 3-dimensional computer modelling of the built environment to an almost infinite number of dimensions, to cope with whole-life construction and asset management issues in the design of modern buildings. This paper reports on the development of a vision for how integrated environments that will allow nD-enabled construction and asset management to be undertaken. The project is funded by a four-year platform grant from the Engineering and Physical Sciences Research Council (EPSRC) in the UK; thus awarded to a multi-disciplinary research team, to enable flexibility in the research strategy and to produce leading innovation. This paper reports on the development of a business process and IT vision for how integrated environments will allow nD-enabled construction and asset management to be undertaken. It further develops many of the key issues of a future vision arising from previous CIB W78 conferences.

Keywords: *Design and construction, vision, IT*

Introduction

CIB W78 as a working commission has been established since 1984. It began as a working commission with a title of integrated CAD and in 1994 it took on a title of IT for Construction. As is shown by Amor and Betts (2001) its work covers a wide and changing diversity of IT issues. Amor and Betts (2001) summarised the major themes that were covered in the last decade of W78 workshops as: -

- Computer integrated construction (CIC): looking at bespoke, and tightly coupled, frameworks for integrated systems that are capable of managing loosely coupled (e.g. Internet-based) integration of design tools utilising the range of evolving data standards
- Construction process: IT in support of process improvement
- Decision support, knowledge-based systems (KBS) and artificial intelligence (AI): including neural networks, case-based reasoning, and distributed AI (e.g. agent-based systems)

On reviewing the technologies and research approaches that have developed in these areas, an implicit vision underlies the overall research approach to the nature of construction process and product delivery. A unified vision can augment both academic and industrial research to improve the performance of the

design and construction process. For the benefit of making the implicit vision more visible, the 3D to nD project vision is used in this paper to illustrate where our ongoing research efforts may relate, and the problems with the way forward for the design and construction industry. It is offered here as a possible enhancement of our developing research vision for us to consider as a way forward for our collective work within W78.

Project context

Designing a new, integrated and co-ordinated building from scratch is part art and part alchemy. It is no longer simply a question of organising a range of facilities on a single site, the needs of a whole host of project stakeholders have to be satisfied. Thus the way in which the building will fulfil the multiple and conflicting expectations of all those parties who form the spectrum of building stakeholders is increasingly becoming the measure of its success. The stakeholders include, not only the organisations and individuals who occupy the building, but also those who have provided it, those who manage it and those who live with it – the community in general.

Buildings have become, and are becoming, more complex. The design not only has to be buildable (in terms of cost and time), but stakeholders are increasingly enquiring about its maintainability, sustainability, accessibility, crime deterrent features, and its acoustic and energy performance. Each of these parameters has to satisfy a whole host of social, economic and legislative conditions, which may even conflict with one another. Further, as each of these factors vary – in the amount and type of demands they make – they have a direct impact on the course and nature of the construction project.
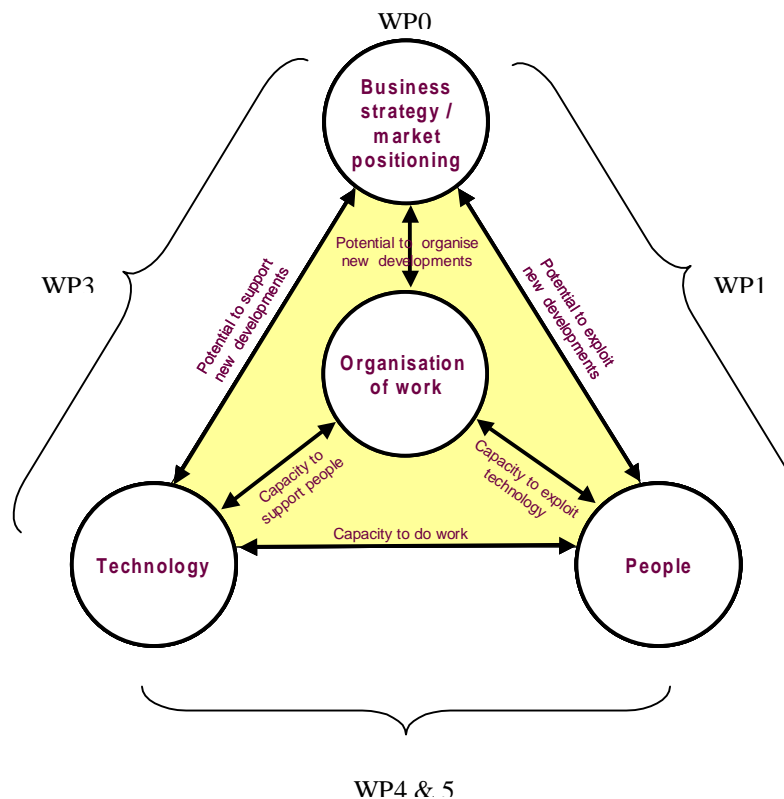
Often, a whole host of construction specialists are involved in instigating these aspects of design, such as Accessibility Auditors, FM Specialists and Acoustic Consultants. With so much information and from so many, varied experts, it becomes very difficult for the project participants to truly visualise the design, any changes and their subsequent impact on the time and cost of the construction project. Changing and adapting the design to aid decision-making can be laborious, time consuming and costly. Therefore, the 3D to nD research project aims to develop a multi-dimensional computer model that will portray and visually project the entire design and construction process, enabling users to 'see' the whole-life of the project. This will help to improve the decision-making process and asset performance by enabling true 'what-if' analysis to be performed to demonstrate the real value of the variables of the design issues. Thus, taking the concept of 3-dimensional computer modelling in the built environment to an almost infinite number of dimensions, the whole life of the construction process and is associated issues in designing modern buildings can be coped with in a holistic way: -

- 3D modelling enables visualisation of the proposed design
- 4D modelling is already been undertaken by the University of Salford in its OSCON and Gallicon projects; and Stanford University. Visual 4D models combine 3D CAD models with construction activities to display the progression of construction over time (Rischmoller et al, 2000)
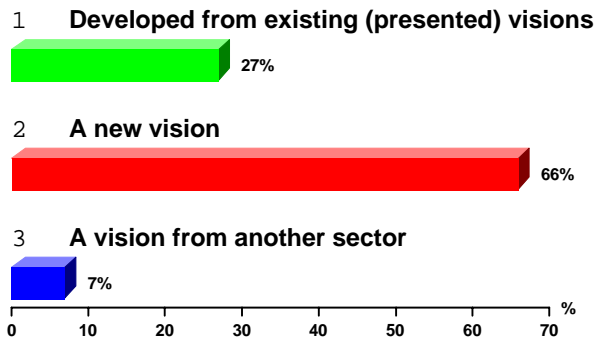
The proposed nD modelling research will develop the infrastructure, methodologies and technologies, many of which have been discussed in previous W78 conferences, that will facilitate the integration of time, cost, buildability, accessibility, sustainability, maintainability, acoustics, crime, lighting and thermal requirements. It aims to combine the leading advances that have been made in discrete information communication technologies (ICTs) and process improvement to produce an integrated prototyping platform for the construction and engineering industries. This output will allow seamless communication, simulation and visualisation, and intelligent and dynamic interaction of emerging building design prototypes, so that their fitness for purpose for economic, environmental, building performance, and human usability will be considered in an integrated manner.

The UK's EPSRC fund the project under a Platform grant. Platform grants were set up in 1998, to allow internationally leading groups the flexibility to implement their own research strategy without being so dependent on smaller funded projects, and more importantly, to foster creativity (EPSRC, 2002). The 3D to nD project is organised into 5 work packages, each of which harness the skills of the multi-disciplinary team namely: -

- WP0: Developing a vision for integrated design
    - o   To develop an IT vision for integrated environments that will allow future nD enabled construction to be undertaken
- WP1: User requirements
    - o   To capture the users requirements of the nD model from potential users of the building
- WP2: Model development
    - o   Existing 4D models will be expanded to allow the development of a fully integrated model supporting the issues raised in WP1, leading to an nD model. The model(s) will be developed to a stage where realistic what-if scenarios can be performed. The model(s) will be supported by a database that will be used to store information that can be visualised using different applications. The issues of model scalability, user interface and information management will be investigated
- WP3: Model validation and testing
    - o   The model(s) will be validated through a series of real life case studies in order to support the further enhancement of the model (s). This is an iterative process, which will be investigated from a technical as well as a business point of view
- WP4: Technology transfer and implementation
    - o   Issues of the diffusion of advance-integrated environments will be studied from a technology management viewpoint. Drawing on generic principles of technology and diffusion, action research case studies will be undertaken with major companies to identify barriers for technology diffusion within construction supply chains, between projects, across organisations and within the industry as a whole. The experience from the action research will be used to derive implementation strategies for technology diffusion that overcome these barriers to be investigated in the future

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What kind of vision do we want to develop for the nD project?

1 **Developed from existing (presented) visions**

27%

2 **A new vision**

66%

3 **A vision from another sector**

7%

At these early stages of the project, work has commenced on the development of a vision for the use of nD models in the future. The remainder of this paper describes how this work has been undertaken and the preliminary findings to date.

Methodology

The first stages of the work sought to develop consensus amongst a 20+ strong group of academics at Salford University working on the project. A workshop was conducted in February 2002 with the multi-disciplinary research team to define the vision for the nD tool; a vision that honours a more theoretical approach, considering the ontological basis for building information. It was agreed at the outset of the workshop that the nD vision should convey the thoughts and desires of the workshop participants with respect to an integrated design/ nD tool. In particular, it would be imaginable, articulating a picture of what the future could/ should look like, and desirable as to appeal to the long-term interest of the industry; being feasible, realistic and having attainable goals, and focused. Further, it would be flexible enough to allow individual initiative and alternative ideas to foster through time, and also communicable, to be easily understood by academics and practitioners alike. Therefore, in order to define such a vision, the workshop participants explored several existing visions governing 'the future of construction.' In addition, an electronic voting tool was used during the workshop to ascertain the consensus of the participants in their own grappling of what they perceived would be the nD model.

Discussion - parameters of the nD tool

The workshop participants, in an attempt to draw from previous work, firstly investigated several documented visions that explored the future of construction with the aim of transferring their propositions to the nD project. Each of the visions investigated covered aspects of the growing trends of construction IT and process improvement.

Research	Description	Website
Construct IT	Defines the use of IT in construction by 2010; explores the management of construction projects and how these processes will be supported by technology	http://www.construct-it.org.uk/
PeBBu	Performance Based Building - European Union funded; the performance approach is the practice of thinking and working in terms of ends rather than means. Investigates the connections between performance objectives and innovation activities	http://www.scpm.salford.ac.uk/cibpebbudomain8/
i2i2	Integrate to Innovate II: innovation in small construction firms - to support cultural change in the construction industry towards continuous improvement	http://www.salford.scpm.ac.uk/projects/i2i2/index.htm
Berkeley/ Stanford	Describes the results of a workshop that discussed the direction of construction research should follow during the next century; the relationship between academic research and practice was also investigated. The workshop funded by the National Science Foundation (NSF) and led by the universities of Stanford and Berkeley involving numerous industrial executives, 1999	http://www.ce.berkeley.edu/%7Etommelein/CEMworkshop.htm
Stanford/ VTT	Findings of research project that explored the future of interoperability and product models in construction; utilises the Delphi technique	

On reviewing the presentations, the workshop participants generally agreed that each of the project visions tended to rely on experts who are enthusiasts for the technologies they were predicting. Moreover,

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predictions in some areas were over optimistic while, in others, new technologies had not been identified. The findings documented through the use of the electronic voting tool confirmed this stance. Although aspects of the existing visions can be strategically placed within the context of the 3D to nD project, it is clear from the results that the majority of our workshop participants wanted to develop a new vision. Following this, the next question facing the workshop participants became clear: at what timescale did they foresee implementation of model – did they favour an applied implementation or blue-sky tool? This factor became the crux of the project during the workshop, as it directed the type of technology that would be entrusted and the subsequent implementation issues of the chosen technology.
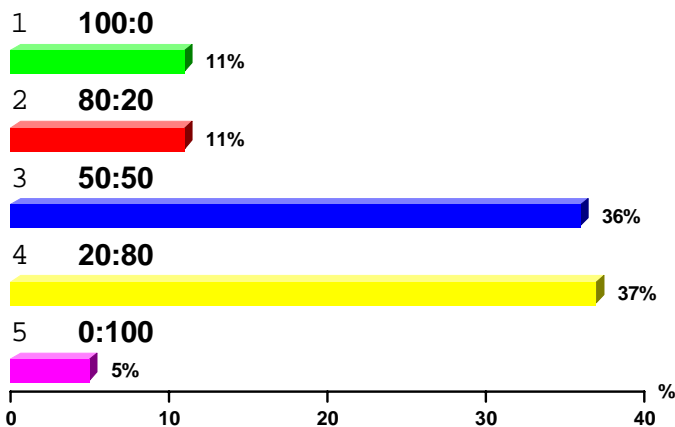
What form of vision do we want to develop on the nD project?

1 **Applied implementation**
15%

2 **Blue sky**
15%

3 **A combination of the above**
70%

%

| 0 | 20 | 40 | 60 | 80 |
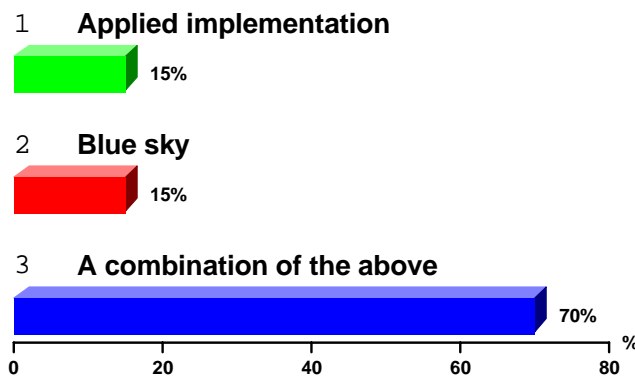
It has long been recognised that the construction industry is not fully utilising current technology available. A substantial part of our work in W78 seeks to address this issue by better understanding management and implementation matters. Drives for new IT systems in the past have usually required financial commitment that was beyond most architects and contractors, or they were not fully implemented by the whole project team. This factor became an important consideration in determining whether the nD tool should encompass a blue-sky or an applied technology approach.

However, the nature of the technology raised a further issue to the project team; by incorporating blue-sky technology now, the final nD tool to be disseminated at the end of the project may not be of a blue-sky nature, as the chosen technology may have already been implemented by industry or that the technology trend would have taken a different direction due to the rapid advancements of IT. Therefore, does the nD tool want to adopt a 'to-be' focus, and if so, to what extent would this focus be? This led to the next question: what proportion did the workshop participants envisage the ratio of applied implementation to blue-sky research on the nD project to be? The result clearly shows that it was desirable to develop a tool that adopted an equal proportion of technology type, although towards more of a blue-sky approach.

What proportion of applied implementation/ blue sky research should we adopt?

1 **100:0**
11%

2 **80:20**
11%

3 **50:50**
36%

4 **20:80**
37%

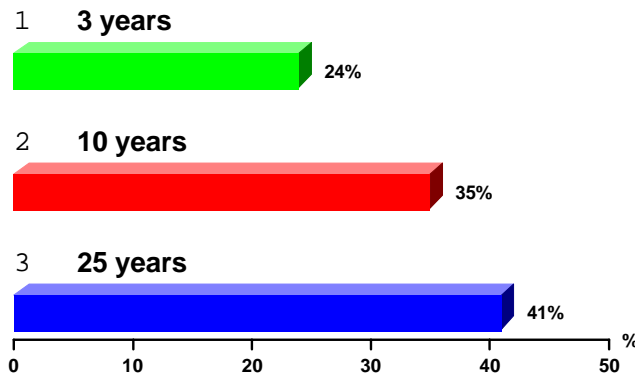5 **0:100**
5%

%

| 0 | 10 | 20 | 30 | 40 |

Clarity was required at first hand to augment what was envisaged as blue-sky/ innovative and applied technology to the workshop participants. The result affirmed that technologies, such as sensor and wireless communication, that are already being harnessed in other industries, and beyond is what is classed as blue-sky technology, and applied technology refers to a tool that is built upon existing practices and applications in construction.

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In the light of this, the research team set out to identify the streams of innovation in IT and communication technology with which construction should follow suit, with the aim of transferring practice to the nD tool. The researchers classified the technologies into two types, namely ubiquitous computing and knowledge management tools: -

- Ubiquitous computing:
  - Describes a state in which computer-based devices become so cheap, seamlessly interoperable and easy to use that they will find application across everyday activities. Its implication on technology, employment and competitiveness will be profound
  - Microelectronics is currently one of the most enabling, although trends towards new processing methods have been identified, especially those based upon molecular and even single electron devices. The use of neurochips and biochips are also rapidly advancing
  - People and devices will be connected in such a way that they will not want to have to worry about network boundaries and incompatibilities. It is for these reasons that smart software (middleware), which plugs the gaps between technological systems, is going to be a critical element of the technological trajectory in ICTs in the coming years

- Knowledge management tools
  - Describes the cluster of software technologies spanning, software programming, data processing and artificial intelligence
  - Data capture, data mining and warehousing technologies are critical technologies and are beginning to achieve widespread use
  - Use of software agents (i.e. software which can be programmed to reflect user preferences in order to automate searching for information, management of data and so on). They will be needed for instance to develop self-regulating computer resources (such as the automatic computer virus vaccines predicted for 2008). Software agents also play a vital role of making the information in systems easier to control for humans
  - Artificial intelligence techniques that are evolving rapidly will be voice, language and pattern recognition systems. Voice synthesis systems are already well developed, but it is expected that by 2006 they will be indistinguishable from human voices. Similarly, translation of natural languages is an area of challenge particularly for European countries. Breakthroughs are expected here through to around 2010 so that portable translation devices and instant text translation will be available for all on-line material. Pattern recognition is more difficult, because the meanings of patterns are often not related to easily recognised variations in their surfaces, distributions or topologies. For example ideogram recognition is not expected until around 2012 and for more general vision systems very low error rates are not expected until beyond 2015
  - An important, component of these artificial intelligence developments will be context sensitive systems. Again, perhaps optimistically, several of the reports suggested that true artificial intelligence, which understands its context and which has the capacities to see, hear, touch and act in a reliably way. However, the history of such predictions is not encouraging. Rather more likely are development software agents (knowledge management tools) in support of human-to-human working in the form of groupware and/ or expert systems management tools. These technologies will be able to learn about user behaviour and adapt their responses, and will even adapt their responses according to social rules

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The result of the question of the proportion of applied implementation/ blue-sky research is confirmed by the subsequent question: at what timescale did the workshop participants foresee implementation of the nD tool? Although the general consensus agreed a long-scale plan (25 years), there was a significant response across all of the options. In order for industry to be able to fully understand the benefits proposed by the nD tool, it was agreed at the outset of the workshop that it must be easily communicable and practical to users. However, this conflicts with the nature of a blue-sky research project, which forces the notion of what is probable, possible and desirable by the resultant deliverable.

What timescale do we want industry to implement the nD tool

1 **3 years** — 24%

2 **10 years** — 35%

3 **25 years** — 41%

Axis: 0 10 20 30 40 50 %

Therefore it was decided to develop a range of scenarios to accommodate all of these factors, each encroaching on varying degrees of applied and blue-sky/ innovative technology. The scenarios would include technology that could be utilised readily and technology/ visions that could be utilised in the future, encompassing multiple timescales henceforth and a vision that would be continuously and iteratively developed so that it would harness the future direction and application of technology.

However, in determining the ease of adoption of the technology (blue-sky/ innovative research) and the necessity of developing a tool that is practical, these issues can be seen as barriers, constraints or opportunities. It was also suggested that the process of construction should also be investigated in addition to developing the 3D to nD product. The Egan report (1998) supports this stance. It suggests that process improvement is a contributing factor to increasing construction performance.

Conclusion

This paper reports on the preliminary findings of a research project based on the outcomes of a workshop that aimed to define the vision for the 3D to nD project that would articulate integrated design. In defining a vision, the workshop concluded that the proposed tool must be imaginable, desirable, feasible, focused, flexible and communicable. However, a number of factors also interplay in its definition. Principally, this includes its timescale, the resultant type of technology that would be fostered and its subsequent implementation issues to construction.

Defining a vision for the future of construction IT, whether for the W78 working commission or for the 3D to nD project, is profoundly difficult due to the multi-disciplinary nature of the research community. Nonetheless, such a vision is required to collectively govern the approaches in innovation taken by many industrialists and academics alike. The growing number of research papers submitted to our annual W78 conferences clearly charts this enthusiasm on the subject. It would be fair to say that in absence of a clear goal or future vision over which we might share some consensus, it is human nature for an individual to try to steer improvement activities towards his or her own goals and areas of expertise. Such as it may be, the construction industry must move away from its silos of creativity in order to reap substantial benefits in cost, time and quality.

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