INDUSTRY-DRIVEN INNOVATIVE SYSTEM DEVELOPMENT FOR THE CONSTRUCTION INDUSTRY: THE DIVERCITY PROJECT

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Collaborative working has become possible using the innovative integrated systems in construction as many activities are preformed globally with stakeholders situated in various locations. The Integrated VR based information systems can bind the fragmentation and provide communication and collaboration between the distributed stakeholders n various locations. The development of these technologies is vital for the uptake of these systems by the construction industry.

This paper starts by emphasising the importance of construction IT research and reviews some future research directions in this area. In particular, the paper explores how virtual prototyping can improve the productivity and effectiveness of construction projects, and presents DIVERCITY, which is th as a case study of the research in virtual prototyping.

Besides, the paper explores the requirements engineering of the DIVERCITY project. DIVERCITY has large and evolving requirements, which considered the perspectives of multiple stakeholders, such as clients, architects and contractors. However, practitioners are often unsure of the detail of how virtual environments would support the construction process, and how to overcome some barriers to the introduction of new technologies. This complicates the requirements engineering process.

Keywords: communication, information sharing, industrial uptake, requirements engineering, virtual prototyping,

BACKGROUND

In the last decade, construction companies have spent a great deal of effort and resources in improving their business processes. New forms of innovative project management, construction management, supported by recent IT developments, have appeared in response to ever-growing pressure from owners to complete projects on time and deliver high quality buildings (Sarshar et al, 2004).

Construction has become an information intensive industry; and a new activity has emerged from the process of managing projects, establishing itself as a discipline in its own right: *information management* (Construct IT, 2000).

Despite the interest and effort applied by leading companies, information management in the construction industry is still in its infancy. Construction projects involve a large

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number of stakeholders such as client, engineers, surveyors, contractor, consultants, etc. There are significant barriers to communications between the stakeholders such as unstructured documentation, process issues, cultural issues, legal issues, contractual and procurement issues, fragmented nature of the construction industry (Kiviniemi, 1999) (Aouad, 1997), (Alshawi, 1996).

Researchers and industrialists have attempted to utilise IT as an enabling technology in order to reduce the problems of communication and information sharing within the construction industry. More recently, in the area of construction IT, researchers have identified the need for an integrated virtual construction environment, which acts as a project repository, during all stages of the lifecycle (Grassi 1999), (Alshawi, 1996), (Kiviniemi, 1999), (Aish, 1999), (Aouad, 1997), (Sawhney, 1999). This aims to improve the communication between the different stakeholders and improve productivity. This environment has proved complex to develop and implement. DIVERCITY was an EU funded research project (1999-2001), which attempted to develop innovative workspace technologies for briefing and design phases of the lifecycle. The workspace was designed to be extendable to other phases of the construction lifecycle, in an aim to develop a holistic virtual construction environment (Sarshar et al, 2004).

In its early years, the CIT research community mainly focused on technology based issues, trying to implement lessons learnt from the IT community in the construction industry. Early prototypes in many research projects investigated data standards and common information models through which heterogeneous computer systems could exchange project information. Many different technologies have been explored. However, in the early projects there was little attention and consideration to the user requirements capture and subsequent implementation of the prototypes (Froese, 1995), (Tanyer, 2003).

Although the concept of virtual prototyping and integrated computer environment has been the subject of research for many years, the uptake of this technology has been very limited due to the development of the technology and its effective implementation (Alshawi & Faraj, 2000).

The discipline of requirements engineering, which is the branch of systems engineering for technical management and requirements capture test and validation of software systems under development, is related to the issues of the development of the technology and its effective implementation. Requirements engineering is a major factor in determining the success of the entire development. It can influence not only the attributes of the systems but how well it is targeted to user needs, the accuracy of the design and specification, the ultimate cost and quality of the final product (Cooper and Wootton, 1998). This is relevant to the development of the technology and the effective implementation (Alshawi & Faraj, 2000).

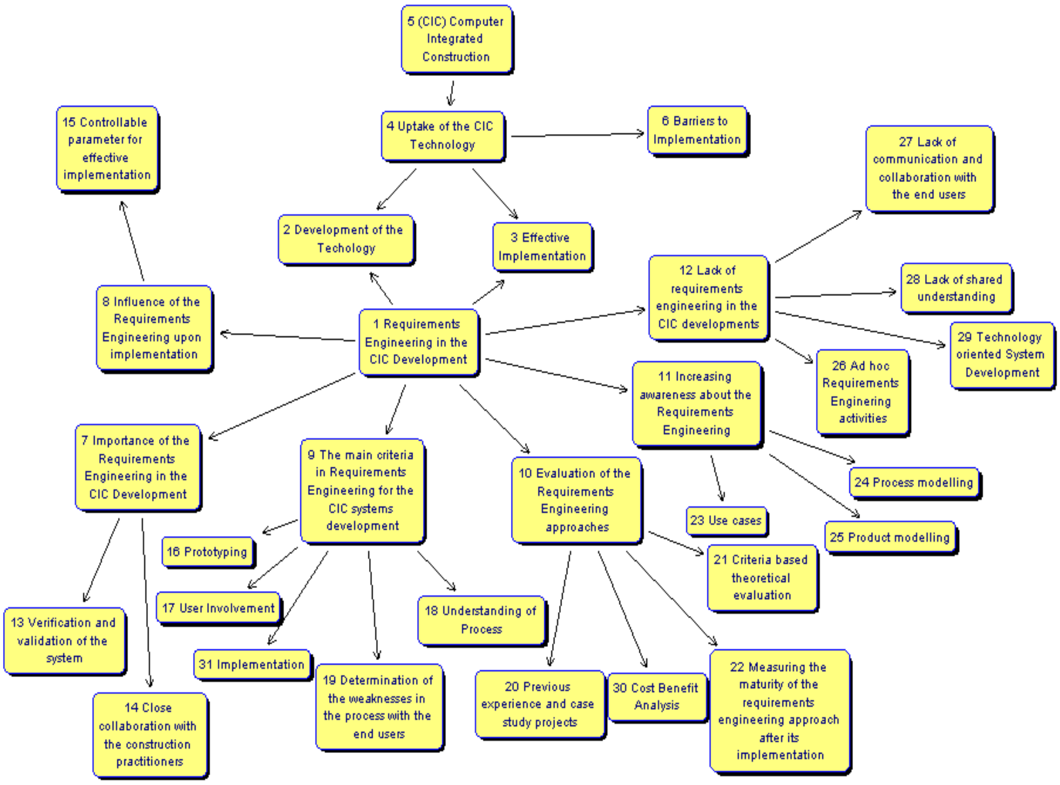
Conducting the appropriate requirements engineering techniques will bring about the following benefits (Arayici, 2004):

- More practical virtual prototyping and integrated computer systems
- Increased usability and ease of use
- Configurable systems
- Flexible and scaleable systems
- Contribution to close the gap between the practitioners and the researchers.
- Contribution to increase the uptake of virtual prototyping by the industrialists

- Support for business process modelling and product modelling

The concept map below developed through semi-structured interviews with industrialists and academics from different backgrounds illustrates the relation of requirements engineering with the development of the technology and its effective implementation for the uptake of the integrated computer environment systems.

Figure 1: concept map of the interview findings about requirements engineering for the uptake of the integrated computer environment in the construction industry



THE DIVERCITY PROJECT

DIVERCITY was an EU funded project that used IFC standards in order to develop a toolkit for shared virtual briefing and design, in the construction industry. This toolkit allows construction companies to conduct client briefing, design reviews, simulate what if scenarios, test constructability of buildings, communicate and co-ordinate design activities between teams.

DIVERCITY developed virtual workspaces that improve communication and collaboration. DIVERCITY allows users to produce designs and simulate them in a virtual environment. The designs are IFC based and can be viewed by all stakeholders within the project team (Divercity Handbook 2003).

DIVERCITY uses a distributed architecture, and enhances concurrent engineering practices during briefing and design. It allows teams based in different geographic locations to collaboratively design, test and validate shared projects. DIVERCITY embraces six applications. These are as follows:

1. Client Briefing: This supports clients and designers during briefing. It provides tools for capturing strategic and spatial requirements and allows

experimentation with alternate spatial layouts, in a visual format (Aspin 2002, Patel 2002).

2. Acoustic simulation: This application automatically reads CAD drawings (in an IFC format), and allows changes to building materials on-line, in an interactive manner. The use can listen and analyse the acoustic qualities of the building, and change the design to achieve desired noise levels (Marache 2002, Coudret 2001).
3. Thermal Simulation: This application automatically reads CAD drawings (in an IFC format), and allows changes to building materials online, in an interactive manner. The user can simulate the energy consumption of the building (/or rooms) and select appropriate material for energy efficiency (Marache 2002, Coudret 2001).
4. Ligting simulation: This provides a realistic simulation of lighting. The user can change and move objects or lights in the building and see lighting simulation in an interactive manner (Thery 2001).
5. One novel characteristic of this application is the mathematical algorithms, which are used for simulation. Lighting simulations generally take a long time (several hours). In most cases, DIVERCITY algorithms allow real time simulation and only take a few seconds. This facilitates interactive and collaborative simulation (Gobbetti 2002).
6. Site Planning: The site planning and analysis application aims to evaluate the space use and safety in the construction site, and provide ways to generate enhanced construction site layouts with respect to time and safety criteria (Tawfik 2001, 2002).
7. Visual Product Chronology: This Visual Product Chronology application provides visualisations over the various data and their interdependencies. In these visualisations the “Time” aspect is crucial. The application links the time tags with the appropriate building components and their data. This results in the visualisations of the status of the building and its components at the selected point of time (Kahkonen 2001).

Information exchange among the applications is possible via IFC standards. Stakeholders in different geographical locations can share an application via communication layer, titled “e-viper”. The communication layer provides the followings.

- Communication between heterogeneous systems, architectures and languages.
- Robust and secure messages transfer
- Time performances to allow real time collaboration
- Multi-user management including identifications and access control.

This paper describes DIVERCITY’s approach for capturing the requirements of construction stakeholders. The construction industry is a large multi-disciplinary industry, with multi-faceted perspectives and requirements. DIVERCITY needed to define broad industrial requirements, and expand them into more detail to capture the briefing and design requirements of the industry, and more specifically the requirements of the DIVERCITY specific applications.

REQUIREMENTS ENGINERING

Requirements as defined by Dorfman (1997) is a software capability that must be met or possessed by a system or system component to satisfy a contract, standard, specification or other formally imposed document which is needed by the user to solve a problem to achieve an objective.

The process of requirements engineering must be planned and managed. There are a number of generic activities to all requirements engineering processes (Sommerville, 2000):

- requirements elicitation
- requirements analysis
- requirements validation
- requirements management

Elicitation is a definition of the system in terms the end user can understand. Analysis is a technical specification of the system in terms the developers can understand. Validation is concerned with showing that the requirements define the system that the users want. Requirements management is the process of managing changing requirements during the requirements engineering process and system development (Lundh 2002).

Although they seem to be separate tasks, these four processes cannot be strictly separated and performed sequentially. Some of the requirements are implicit in the working practices, while others may only arise when design solutions are proposed. All four are performed repeatedly because the needs are often impossible to realize until after a system is built. Even when requirements are stated initially, it is likely they will change at least once during development and it is very likely they will change immediately after development.

Since the attention is contemporarily on the user requirements and specification in system development, the state of the art techniques and approaches have emerged such as contextual design technique and use case driven requirements analysis and agile requirements engineering processes.

DIVERCITY'S APPROACH

DIVERCITY is a large-scale, highly innovative and interactive workspace. It is concerned with the development of interactive systems that cannot be treated simply as incremental improvements over existing construction IT solutions on the market. In such cases it is not possible to identify user requirements on the basis of empirical techniques, as there are no instances of the use of the product (or similar products) from which to collect data. Consequently, the developers of innovative products must proceed by envisioning the use of the proposed product (Dearden 1998).

In innovative systems, such as DIVERCITY end-users are often unsure of what they want and what to expect, at the start of the project. The testing and inspections improve end-user understanding by demonstrating what is possible. The users can then provide more detailed requirements and explore how the systems would fit into their business processes.

The DIVERCITY's requirements engineering team consisted of five organisations spread across four EU countries. The team comprised of two universities with construction IT background, a large firm of architects, a medium sized contractor, and a large engineering consultancy firm.

The importance of requirements engineering was well understood amongst the project team. However, the processes and methods for requirements engineering evolved through the project. Initially team members had individual ideas and perceptions. Different methods were explored concurrently, but independently of each other. It took the team over a year to evolve a shared understanding of the processes and methodologies. There was then a learning period, for all team members to become familiar with all the deployed methods.

DIVERCITY'S METHODOLOGY

DIVERCITY reviewed a number of methodologies and finally used a combination of techniques. The DIVERCITY requirements approach is relatively mature compared to the other CIC prototypes. It is detailed down into three category; use case driven requirements analysis, contextual design, incremental prototyping with user tests, each of which are strong techniques to undertake the aspects of requirements elicitation, requirements analysis and requirements validation respectively.

UML Phase

DIVERCITY initially intended to use use-cases and UML as means of requirements capture. CIT (Construct IT) group in the project team was familiar with UML and relying on its popularity in software development. Furthermore, it provides object-oriented development and fits with well some other technical aspects such as IFC. In addition, technical team also supported to use of UML for requirements capture. Therefore, use case driven analysis were selected for requirements elicitation and analysis and rational rose enterprise edition software tool of UML were selected for the development of high level use cases and for the decomposition of these use cases into further detail object diagrams before committing them to code.

In use case driven requirements capture, the requirements workflow proposed by RUP (Rational Unified Process) was intended to use in order to communicate the complex top-level industry requirements and progressively break into more detail. Furthermore, to manage the large scale and evolving industry requirements, Boehm's (1996) recommendation for a "win-win spiral model" were also taken on board, where the advises on creating three critical milestones, i.e. (i) lifecycle objectives (ii) lifecycle architectures and (iii) operational capability (shelbourn et al, 2001).

Contextual Design Technique

Often requirements modelling starts with UML (Unified Modelling Language) based on object modelling of the system with efficient tools such as Rational Rose (http://www.rational.com). That results in taking too little consideration to understand user needs and user interface design as well as quality requirements (Regnell et al, 1995).

There are not so many well-formalised methods to support the entire design of a product like DIVERCITY. Due to its well worked out user centred approach the Contextual Design method (Beyer and Holtzblatt, 1998) is chosen to try to early take into account the end user work practice and interface requirements. Furthermore, because system developments which start with UML based object modelling with efficient tools like Rational Rose from Rational Software Corporation (http://www.rational.com) takes too little account to early conceptual analyses of user requirements and user interface functionality (Christiansson et al, 2001). The risk is obvious that important properties of the final product with regard to end use are overlooked. Besides that, use case models are loose collection of use cases (Regnell et al, 1995).

Contextual Design methodology has five different types of Work Models. These are as follows;

- Flow, representing communication and co-ordination necessary to do work (roles, responsibilities, actions/communication topics, and spaces which are regarded in DIVERCITY as project internal or project external memories and virtual/physical spaces).
- Sequence, showing the detailed work steps necessary to achieve intent. Sequence models can reveal alternate strategies to achieve the same intent.
- Artefact, showing objects created to support the work
- Culture, representing constraints on the work caused by policy, culture or values, formal and informal policy of the organisation, business climate, self image, feelings and fears of the people in the organisation, possibility for privacy.
- Pyhsical, showing the physical structure of the work environment as it affects the work

These work models were developed in close collaboration between the user groups of the project team. Afterwards, the storyboarding was conducted. To do so, the user group held a workshop, which ran very well and resulted in emerging a shared understanding amongst the end users. The user group focused on the further details how the DIVERCITY system should function and how the stakeholders such as client, architect, engineer, and contractor should act to conduct their duties using the relevant functions of the DIVERCITY system. 15 scenes were developed and in each scene the duties of the construction stakeholders and how they should interact to conduct their duties collaboratively were explained. Furthermore, the storyboard enabled the technical team also to understand the requirements clearly and the shared understanding was extended amongst the technical team as well as the end users.

Because the storyboarding enabled a shared understanding amongst the project team, it was further developed to use in the testing process. The requirements specification was updated through storyboarding during the period of the DIVERCITY tests. Furthermore, storyboarding enabled close collaboration between the project team.

Incremental Prototyping with User Tests

In development of innovative systems like DIVERCITY, the first thing that is very important is to have early prototypes to demonstrate in front of the end users. Therefore, the released early prototypes were undergone black box testing conducted by the project user groups. A quite well documented strategy for the testing process was prepared. Besides, the well-structured testing documentation enabled the user group to conceive how to contribute to the testing process and interact and collaborate with each other throughout the testing process. From the very beginning of the testing process, the distributed team worked very closely in a collaborative manner. The testing process played a major role in evolving the requirements and providing a spiral development process.

In DIVERCITY, testing lifecycle incorporates three main testing phases: Alpha, Beta and Final testing. The DIVERCITY tests were also called as black-box tests. This is because, DIVERCITY tests centre on testing the programs against the written specifications and test observes the programs as black-boxes and is totally unconcerned with the internal structure of the programs (Lewis, W.E., 2000).

Furthermore, there was a symbiotic relationship between the end users and the developers in the DIVERCITY project. The entire tests in the lifecycle were conducted by the end users not the developers. The developers released the prototypes and the end users, who were distributed across Europe, tested the prototypes continuously in a collaborative manner with respect to the defined test criteria above. They continuously provided feedback to the developers throughout the test phases.

The most effective way to reduce risk is to start testing early in the development cycle and to test iteratively, with every build. With this approach, defects are removed as the features are implemented (rational white paper, 1999). Each testing phase-Alpha, Beta, Final- is conducted in an interrelated and continuous and iterative manner. The user group employed the UML test workflow to conduct the black box tests in a stage wise manner. A typical UML workflow encompasses the stages: plan test, design test, implement test, execute test in integration tests stage, and execute tests in system test stage.

DISCUSSION

During the introduction of the paper it was discussed that a key objective of requirement engineering in the construction IT research is to increase the level of technology uptake and reduce the gap between research and practice.

DIVERCITY spent much effort in capturing requirements directly from the end user community, who formed the requirements engineering team. Many methodologies from the requirements engineering community were reviewed and eventually an integrated methodology was adopted and shared among the end users.

As such DIVERCITY is viewed as a successful EU research project. Its applications are technically advanced and beneficial to construction practitioners.

However, the construction industry in Europe operates on tight operating margins and is slow in adopting new technologies and working methods. The industry is fragmented, with many business interests and parties operating during each stage of the life cycle. Any innovative application needs to take account of requirements at three different levels, i.e:

- The individual practitioner;
- The project; and
- The organisation and business (for each stakeholder in the construction team).

When these requirements overlap and compliment each other it should be possible to introduce innovative solutions to the industry.

The DIVERCITY requirements engineering approach concentrated on practitioner requirements, and technical project requirements. However, the commercial project requirements, and business needs have been mainly ignored. It is possible that virtual environments such as DIVERCITY could increase project costs, without sufficient benefits, or introduce excessive change in the process and working relationships among stakeholders.

Tanyer (2003) addresses that in bridging this gap, the research methodologies used in most construction IT research projects are incomplete. Generally the research stops after the production of a working prototype. It is necessary for all construction IT research to continue with testing on live construction projects. This will allow capturing project and business impact and requirements.

The business requirements, and therefore the software requirements, will vary according to the construction sector (e.g. housing, office, etc.). Therefore researchers must explore the business gains for each specific sector before generalising the results for the whole industry.

Within DIVERCITY it was paramount to explore requirements from the business and financial perspective, alongside the technical requirements. It was essential to have a financial vision, in parallel with the technical and process vision. The framework and methodologies from the software sector, which were reviewed, disregarded these dimensions. Construction IT research needs to tailor or develop requirements' engineering methodologies which consider these critical dimensions.

Due to the rigorous capture of end-user requirements, at a practitioner level, some of the DIVERCITY applications have been used in some construction projects. For example, the lighting application has been used in a French museum project, and the collaborative applications have been embedded in software for other industries. However, to date, most DIVERCITY applications have not found their way into the commercial construction market place.

SUMMARY

In this paper, the DIVERCITY research project is introduced. It developed seven applications including the communication layer for briefing and design. The key challenge for novel environments such as DIVERCITY is the lack of uptake by the industry. However, communications and networking will be a major topic over the next ten years Aouad (et al, 1998). Therefore, the demand on integrated computer environments such as DIVERCITY will be high because it is these systems will provide communication and networking. Alshawi and Faraj (2000) raised that the uptake of this technology is limited due to the development of the technology and its effective implementation. The development of technology and effective implementation of the technology is considered in the requirements engineering discipline, which is the branch of systems engineering in IT industry.

Hence, the paper focused on the requirements engineering methods and processes, as a means to improve the technology transfer rate. Many early CIT research projects paid little attention to requirements capture. DIVERCITY is one of the few projects, which spent significant time and resource in capturing end user requirements. This paper discussed the methods and processes deployed by the DIVERCITY project. These may prove beneficial for future CIT research projects.

The strengths of DIVERCITY approach were in adopting an incremental prototyping development cycle, which included practitioners from different backgrounds. However, DIVERCITY requirements engineering must expand to:

1. Take account of the business benefits and financial impact of this workspace on construction projects as well as individual firms;
2. Include live piloting on real construction projects, in order to assess the unforeseen impact on businesses and working practices.

Although there has been some uptake of DIVERCITY deliverables within the industry, there could be more achieved in bridging the technology transfer gap. It is important for the CIT community to plan live piloting of research results, as well as the assessment of financial impact of deliverables on businesses, more actively in the research methodology.

REFERENCES

Aish, R., (1999) Migration from an Individual to an Enterprise Computing Model and its Implications for AEC Research. Berkeley-Stanford CE & M Workshop: *Defining A Research Agenda*, Stanford.

Alshawi M, Faraj I, (2000) Integrated Construction Environments: Technology and Implementation, *Construction Innovation*, Volume 2, Number 1.

Alshawi M, (1996) SPACE: integrated environment. *Internal Paper*, University of Salford, July 1996

Alshawi M, Aouad G, Faraj I, Child T, Underwood J, (1998) The implementation of the Industry Foundation Classes in Integrated Environments, *CIB W78 Conference*, Sweden, August, pp55-66.

Aouad G, Marir F, Child T, Brandon P. and Kawooya A. (1997) Construction Integrated Databases- Linking design, planning and estimating, The OSCON approach, *International Conference on the Rehabilitation and Development of Civil Engineering Infrastructures* American University of Beirut, pp 52-60.

Aspin R, Fernando T, (2002) Development and Exploration of Conceptual Building Function-to-Form Relationships, *ECPPM 2002 European Conference of Product and Process Modelling eWork and eBusiness in AEC*, Portoroz, Slovenia.. 9-11 September 2002

Beyer H, Holtzblatt K, (1998), *Contextual Design. Defining Customer-Centered Systems*, San Francisco, Morgan Kaufmann Publishers.

Christiansson P, Svidt K, Skjærbæk J O, Aaholm R, (2001), User requirements modelling in design of collaborative virtual reality design systems *International Conference on Construction Information Technology* Mpumalanga, Soth Africa, 30 May - 1 June 2001. (pp. 40/1 - 40/12)

Construct IT (2000) Construction Modelling Methodologies for Intelligent Information Integration (COMMIT), Construct IT Centre of Excellence, UK, ISBN 1-900491-76-1

Cooper R., Wootton, A., (1998) Requirements Capture: Theory and Practice, Technovation 18(8/9) pp.487-511

Coudret F, Lombardo J, Marache M, Soubra S, (2001) DIVERCITY: A VR application for the Construction Industry, Virtual Reality International Conference, Laval Virtual 2001, 16-18 May 2001.

Dearden, A., Howard, S., 1998, Capturing User Requirements and Priorities for Innovative Interactive Systems, Australasian Computer Human Interaction Conference, November 29, December 12, 1998, Adelaide, S. Australia

Divercity Handbook (2003) The Divercity Project: A Virtual Toolkit for Construction Briefing, Design and Management, University of Salford, UK.

Dorfman M, Thayer H, (1997) *System and Software Requirements Engineering*, (2nd edition), IEEE Computer Society Press

Froese, T., (1995), “Models of Construction Process Information”, Computing in Civil Engineering, American Society of Civil Engineers.

Gobbetti,E., Spanò,L., Agus.,M., (2002) Hierarchical higher order face cluster radiosity *Technical Report CRS4 TR/, CRS4*, Centre for Advanced Studies, Research, and Development in Sardinia, Cagliari, Italy. March 2002.

Grassi M.D, Zorgno A.M, (1999) The Virtual Construction Enterprise, *Berkeley-Stanford CE&M Workshop*, Stanford 1999.

Kähkönen K, (2001) Visualising the Construction Progress *Industrial Horizons (VTT customer magazine)*, Finland, April 2001

Kiviniemi A, Laitinen J, Lautanala M, (1999) Defining a Research Agenda for AEC, *Berkeley-Stanford CE&M Workshop*, Stanford 1999.

Lewis WE, (2000) *Software Testing and Continuous Quality improvement*, Plano, Texas, Software Testing Associates Inc.

Lundh E, Sandberg M, (2002) Time Constraint Requirements Engineering with Extreme Programming -An Experience Report, *IEEE Joint International Requirements Engineering Conference*, Essen, Germany

Marache M, Coudret F, Lombardo J, Aspin R, Tawfik H, Fernando T, (2002) *Virtual Environments for the AEC sector* eWork 2002, Prague, The Czech Republic 16-18

Patel N, Campion S, Fernando T, (2002) Evaluating the Use of Virtual Reality as a Tool for Briefing Clients in Architecture, *Information Visualisation 02*, London, July 2002.

Rational white paper (1999) The rational Approach to Automated Testing, USA, http://www.rational.com/products/whitepapers/100581.jsp

Regnell B, Kimbler K, Wesslen A (1995) Improving the Use Case Driven Approach to requirements Engineering, *Proceedings of Second IEEE International Symposium on requirements Engineering*, York, UK, March 1995

Sarshar M., Christiansson P, and Winter J (2004) Towards Virtual Prototyping in the Construction Industry: The Case Study of the DIVERCITY project. In: Brandon P, Li H, Shaffii N, Shen Q (Eds), INCITE Conference, 18-21 February 2004, Langkawi Malaysia. Designing, Managing and Supporting Construction Projects through Innovation and IT solutions, Vol. 1, 581-8.

Sawhney A, (1999) Research and Development Plan for the AEC Industry, *Berkeley-Stanford CE&M Workshop*, Stanford 1999.

Shelbourn M, Sarshar M, Aouad G, (2001) DIVERCITY, A Construction Industry Case Study of User Requirement Capture, *Proceedings of ninth IEEE International Symposium on Requirements Engineering*, Toronto, Canada.

Sommerville, I., Sawyer,P. (1997), Requirements Engineering, England, John Wiley&Sons Ltd

Tanyer AM, (2003) *Bridging the Gap Between Research and End-users in Computer Integrated Construction*, PhD Thesis, SCPM, University of Salford, UK.

Tawfik H, Fernando T, (2001) A simulation environment for construction site planning, *The 5th IEEE International Conference on Information Visualisation*, London, UK, 25- 27 July 2001

Tawfik H, Fernando M, (2002) A simulation tool for multi-perspective site layout analysis *ECPPM 2002 European Conference of Product and Process Modelling* eWork and eBusiness in AEC, Portoroz, Slovenia.

Thery S, Da Dalto L, DupuyY, Balet O, Paulin M, (2001) Realistic Rendering in Interactive Architectural Design, *VRIC*, 16-18 May 2001, *Virtual Reality International Conference*, Laval, France.