AN INNOVATIVE APPROACH TO IMPROVE COLLABORATION IN A FUTURISTIC DESIGN REVIEW

May Bassanino[1], Gilles Gautier, Kuo-Cheng Wu, Terrence Fernando and Jens. Skjærbæk[2]

[1]*Future Workspaces Research Centre, University of Salford, Manchester M5 4WT, UK*
[2] *COWI A/S, Aalborg, Denmark*

The benefits of IT-based innovation and collaborative workspaces are well recognised in the construction industry to improve its productivity. Enterprises realised their need for sophisticated ICT based working environments to overcome geographical barriers separation between teams and promote social interactions providing appropriate design tools and intuitive interfaces to assess design from various perspectives. Since then, such demands became the drive for companies to adopt new forms of workspaces to promote social interaction between team members and allow efficient collaborative working. These new technologies such as networking, Virtual Reality, collaborative interfaces started influencing the way enterprises work. A futuristic scenario was developed in the course of the on-going CoSpaces European project with a vision of using new technologies to create workspaces with intuitive collaborative interfaces. The expected benefits are fewer meetings are required, with more design alternatives to discuss and better shared viewpoints among the various competencies of the meeting. This will improve communication, increase collaboration among the project teams and eventually improve the industry's productivity. The work does not only demonstrate the technological requirements to develop such collaborative interfaces as the CoSpaces platform for collaboration but it is further extended to evaluate the effective use of implementing this framework by a group of end users to achieve better collaborative solutions in the construction industry. The design review scenario implemented in a living lab setting, reveals the outcomes of the end users' experience using the human-centric technologies developed in CoSpaces project to review and solve design problems in construction.

Keywords: collaboration, co-located workspace, CoSpaces technologies, evaluation.

INTRODUCTION- MOTIVATION FOR COLLABORATION

The current performance in the construction industry is well recognised by governments as well as clients who are continually seeking to bring in change to improve productivity in construction.

Despite the barriers behind the deployment of collaborative workspaces and the use of virtual technologies in the construction industry whether attributed to the lack of IT-related investment (European Commission, 2006) or the readiness of these organizations for new

[1] m.n.bassanino@salford.ac.uk; g.gautuer@salford.ac.uk; kuo.cheng.wu@gmail.com; t.fernando@salford.ac.uk

[2] JEO@cowi.dk

technologies (Alshawi et al, 2008), there is equally a number of drivers to improve business processes together with products to compete in the global financial market (Alshawi et al, 2008 and Fernando, 2008). Due to the unique nature of the construction industry and the complexity of its projects, a typical construction project involves a large number of direct and indirect stakeholders representing a diversity of disciplines, skills and cultures (Lu & Sexton 2006). However, these stakeholders need to work together to produce the final building and therefore tremendous amount of coordination and collaboration is necessary to ensure that the stakeholders share a common understanding of the project to avoid delays and unnecessary reworking. Moreover, it has well been reported that communication among the project team members is one of the key factors in the success of any project (Bassanino et al, and Blyth and Worthington,).

Collaboration is a process aiming at achieving "shared thinking, shared planning and shared creation" (Montiel-Overall, 2005), so, it is important to share viewpoints in order to make decisions to solve unplanned events or to foresee later issues. To ensure that all stakeholders share the same viewpoints about the project, meetings are organised on a regular basis. These meetings take place within three different settings; Distributed team workspaces where teams are separated geographically, Co-located team workspaces where teams come together dynamically in a single technology-driven meeting space, Mobile team workspaces where teams can communicate directly with colleagues on site. The co-located meeting which is the focus of this paper takes place during the project life cycle with the objective to identify potential issues among the various competencies to ensure that all stakeholders share the same viewpoints about the project so decisions can be made and an optimised way forward can be agreed.

The futuristic scenario presented in this paper was developed in the CoSpaces project with a vision of using new technologies to create workspaces with intuitive collaborative interfaces. This will provide the opportunity to bring together critical data and stakeholders in ways where more design alternatives can be discussed during the meeting with better shared viewpoints among the meeting's participants. This will reduce the number of meetings, improve communication and consequently reduce delivery times. This work aims to find out whether the CoSpaces system can facilitate collaborative design work by improving group's performance, providing project teams with intuitive design and annotation tools to assist them in sharing various viewpoints by creating real-time collaborative working environments to enable project teams explore more design alternatives.

This work will not only demonstrate the technological requirements for developing such a system, but it is extended to evaluate the CoSpaces platform taking both the organisational and social aspects into account to improve the efficiency of co-located meetings enabled by a better shared understanding between the participants.

BACKGROUND- RELATED WORK

As stated in the Future Workspaces Roadmap project (IST 2001-38346), the state-of-the-art would allow real-time collaboration between project teams based on distributed sites to be reformulated in the construction industry, however critical issues such as security and network bandwidth limitations and their associated costs were restricting effectiveness. Enterprises in the construction industry realised their need for sophisticated ICT based working environments to overcome geographical barriers separation between teams and promote social interaction providing appropriate design tools and intuitive interfaces to assess design from various perspectives. Since then, such demands became the drive for companies to adopt new forms of workspaces to promote social interaction between team members and allow efficient collaborative working. Thus, new technologies such as networking (GRID, wireless), high performance computing, Virtual Reality, collaborative interfaces and simulation technologies started influencing and changing the way enterprises work.

A number of leading CAD industries have been developing some collaboration functionality within their existing commercial CAD products and services (Sharma et al, 2006). Some products were developed for off-line collaboration only such as eDrawings Professional, others such as Unigraphics NX and CollabCAD products were developed to support real-time collaboration, however limited number of participants can access the system to collaborate in the case of CollabCAD.

Moreover, over the last ten years, a number of European projects were dedicated to develop software frameworks for virtual environments with account to economical, organisational and human factors to ensure functionality, usability and acceptability from the work force. However, many of them were either developed for distributed environments only such as VR Juggler and DIVE (Frecon and Stenius, 1998), WISPER (Faraj et al, 2000), DIVERCITY project (Sarshar et al, 2003 and Arayici, 2004) and COVISE, or for mobile workspace only such as MOBIKO (Steinmann, 2004).

Despite the above developments, the area of user interface still requires significant development for groups of multi-disciplinary stakeholders and site workers as the current user interface does not provide stakeholders with the facility to have their input into the design (Fischer, 2008). Besides, these interfaces need to be developed in an intuitive manner to enable users to use them with little or no training (Taylor et al, 2004). In addition, development are needed to enhance collaboration between participants which will lead to have a far more complete appreciation of the impact of inter-disciplinary decisions during design process resulting in better designs (Miles, 2005). The CoSpaces project is therefore developed to offer better user interfaces that focus on engaging groups of stakeholders from different disciplines and background to achieve a more effective and efficient early project design phase covering the three workspaces of Co-located, Distributed and Mobile. Unlike most of the above systems, CoSpaces provides public/private workspaces where users have the flexibility to share own data in the public workspace with other participants or access own data in the private workspace. This facility coupled with providing tools for annotations, marking to facilitate discussion and sharing of viewpoints during meetings taking into account the human centric issues of all users and stakeholders together with organisational issues to support collaborative working (Arayici et al, 2005 and Fernando, 2008) and better integration of project information throughout the whole product life cycle to be facilitated through a computer environment.

SYSTEM PLATFORM

The CoSpaces framework consists of several main modules such as Collaboration Broker (CB), Dynamic Session Manager (DSM), Knowledge Support Management (KSM) and Application Controller (AC).

In the co-located meeting, all participants used their laptops with the CoSpaces system installed on each machine. They used the Living Lab Infrastructure, referred to Active

Distributed Development Space (ADDS). The system ran on Windows XP or Vista operating system and the laptops were equipped with current standard CPU/RAM/graphic card. A plasma display available in the meeting room was used to project the design of the selected participant's workspace to facilitate interactive brain storming sessions among the meeting's participants.

The core system components consisted of: model data server, several desktop clients to support the multi stakeholders in the project team (such as Architect, Structural Engineer, QS applications, etc) and immersive environment for the end user to validate the design. However, evaluating the immersive environment with end users was left to be tested later on. The model data server and desktop clients were implemented using TechSoft's Hoops 3D Graphic Library, while the Immersive environment utilized the OpenCOVER rendering engine. All these components were network-linked using the TechSoft's Hoops Net toolkit as illustrated in Figure 1.

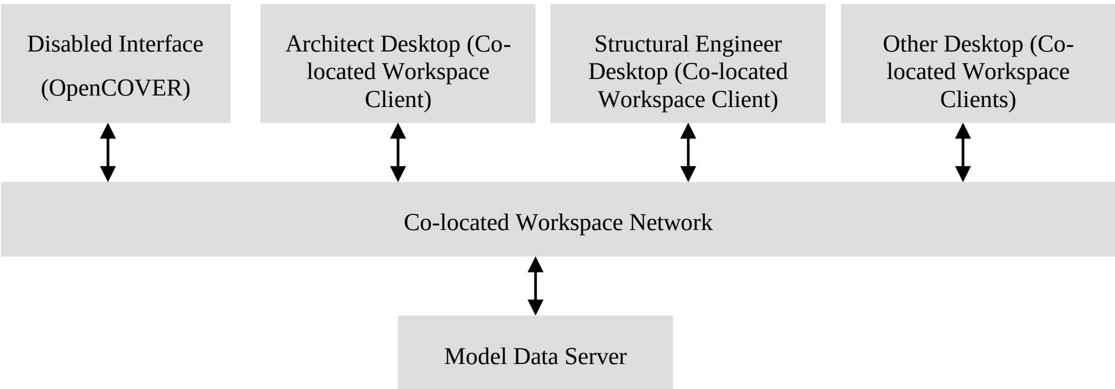

Figure 1- The core system components

The following section highlights some of the CoSpaces technical features used for supporting collaborative working:

The CoSpaces intuitive design and annotation tools

In order to facilitate discussions and investigate design alternatives, the system provides design, annotation and mark-up tools with intuitive interfaces to assist in the brain storming sessions during co-located meetings in order to assist the participants to assess design from various perspectives. For example, if any participant adds the mark-up and annotation to the design during a co-located meeting; the annotations propagate to the other participants across the network. The system also provides a hierarchy browser to enable participants to show/hide the parts based on the service layer.

The Public/Private workspaces

Unlike pervious systems discussed earlier in this paper and in order to support the users' collaborative activities, the workspaces installed on the client sides provide two types of spaces: Public Team Space (PTS) to facilitate the main design review activity, facilitated by the meeting's chair and a Private Space (PS) to facilitate personal exploration of design issues independently without distracting the activities on the Public Team Space. Thus, any participant can open up a private architect desktop in his Private Space and load data to evaluate the overall design without distracting other users. The current system doesn't utilize the CoSpaces Foundation Platform. However, it is planned to embed the functionality into a web-based browser in the following phases. For that purpose, most of the core CoSpaces framework such as Collaboration Broker, Knowledge Support, Dynamic session Manager and Application Controller were used.

The CoSpaces portal

The CoSpaces portal browser serves as the front end and allows users to configure the meeting settings. It contains information about projects, meetings, participants, documents. Participants can use it to visualise the meeting agenda and any documents they uploaded into the system prior to the meeting. Furthermore, as all stakeholders are made known to the system with their profiles, they can be called if necessary during the meeting regardless of their geographical location and collaborate with those present in the meeting using the CoSpaces technologies. However, the portal evaluation was not included here and was left to be tested separately at a later stage.

THE FUTURISTIC DESIGN REVIEW SCENARIO IN CONSTRUCTION

The scenario developed in the course of the CoSpaces project illustrates a futuristic vision of using new technologies to improve co-located meetings. The expected benefits are more efficient meetings with the possibility to examine more design alternatives, shared viewpoints of the various stakeholders to achieve appropriate solution collaboratively which will increase collaboration among the project teams and improve the industry's productivity. The case study (Gautier et al, 2008) is based on a futuristic design review meeting to discuss redesigning a bathroom for wheel chair users, where the floor area was reduced during construction due to the addition of a separate installation shaft and a ventilation system in the space in order to respond to new requirements for fire protection and safety. As a consequence, the bathroom has to be redesigned, but must include the same elements as previously planned: a close-coupled WC, a basin, a bath tub, a wall hung cupboard and a window (Figure 2). During the meeting, the new proposed design was validated by a range of stakeholders in the project team representing different perspectives, interests and concerns.

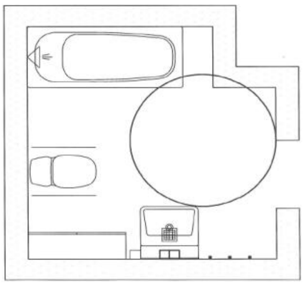

Figure 2- Possible setting for the bathroom's elements

The futuristic co-located scenario focuses on the impact of the design change involving a number of stakeholders taking on defined roles. For the purpose of the evaluation, the futuristic scenario was designed as close as possible to simulate real life meetings. Also, it is important to point out that at this stage, we did not include all the identified stakeholders (Figure 3); however, selected stakeholders were identified to include a representative from each of the main groups (End users group, Client group, Consultant group and Main contractor's group) to ensure that all viewpoints are represented in the co-located meeting.

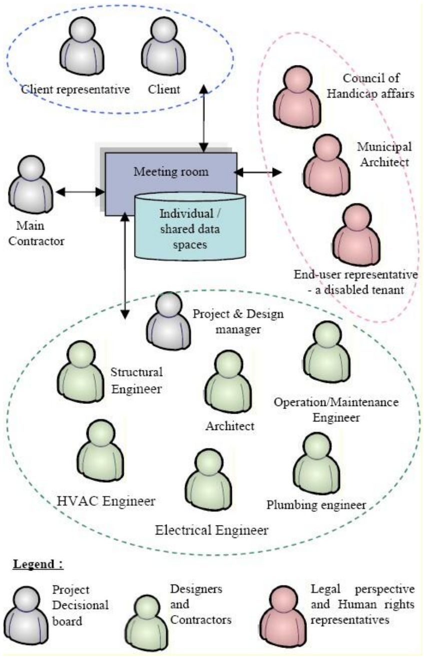

Figure 3- The Co-located meeting participants

Evaluation of the Co-located Workspace

Prior to the evaluation of the Co-located workspace, a trial session with a group of academic partners took place to test the system technically and check its reliability before involving the end users. The evaluation was set up with two groups: Construct IT for Business (an industry-led non-profit making collaborative membership-based network) at the University of Salford and COWI (a leading international consulting group in engineering, environmental sciences and economics) in Denmark. A HD camcorder was used to record the sessions.

The objective of the evaluation was to test the effective use of the CoSpaces technologies on improving the efficiency of co-located meetings and collaboration. Based on the users' requirements captured earlier in the project, evaluating the co-located workspace was set up to measure the system's utility, usability of CWE (Collaborative Working Environments) and the system's likeability (user attitudes and experience). More specifically, the evaluation aims to answer the following research questions:

- Can the CoSpaces system facilitate collaborative design work by improving group's performance?
- Can the system make collaboration easy by providing project teams with intuitive design and annotation tools?
- Can the system create/achieve real-time collaborative working environments to enable project teams explore more alternatives?

To find out how the CoSpaces system has an effect on collaboration, a set of closed questions with semantic scales were used to test the system's utility, usability and likeability, while open questions were utilised to collect the participants' views on the collaborative process in CoSpaces. Also, as participants vocalise thoughts, goals, feelings and talk about their actions whilst performing a task (Bainbridge 1990), the Verbal Protocol method was selected to validate the collected data and to also understand the users' reasoning when interacting with the system. Interactive discussions between the participants and the facilitator were all recorded while observing of the participants' performance.

The Co-located workspace evaluation started when the stakeholders came together to attend a co-located meeting via the CoSpaces platform to produce an optimised design. As the participants entered the meeting room, each was connected to their laptop with the CoSpaces system installed on it with the users' interfaces being adapted to the participants' roles and profiles (for example, architect, structural engineer, end user, client, etc). The session started with the group receiving an introduction by the facilitator about the CoSpaces project, the exercise, its objectives and the tasks to be performed to ensure that all participants have the same briefing before they start. This was followed by a technical demonstration of the workspace functionality (such as display of images, moving objects around and annotating). The participants then had a hands-on session where they could explore the features of the system and familiarise themselves with the provided tools.

Following the demonstration and the hands-on session, the co-located meeting started with the architect giving a presentation about the design problem. During the presentation, the architect annotated the 3D presentation of the bathroom model and shared the possibility of replacing the bath with an accessible-shower unit. Collaboration was facilitated here through the use of public/private workspaces. First, all participants shared the same view of the model on a large display and their screens were automatically updated with changes and annotations. After the change took place, all participants studied the new proposed design in their own private workspace from their own expert perspectives (such as electrical installations, structural implications, plumbing service and end user acceptability).

During the co-located meeting, participants discussed the new proposed layout and its implications from their individual assessments and validated the new design proposal. The design tools available in the CoSpaces system provided the possibility for the meeting's participants to examine a number of alternative design solutions of changing the bathroom's layout and sharing various viewpoints. Once an acceptable solution for a new design layout was reached and validated by all the meeting's participants, the session was terminated.

The scenario presented here illustrated the impact of human-centric technologies on collaborative working in a co-located setting. The state-of-the-art technologies ensured that the multi-disciplines stakeholders can effectively work together sharing the same data at the same time within the same context. The set of tools provided in CoSpaces helped participants to better communicate ideas and share of viewpoints. Advanced collaboration led to better decisions which ultimately improved the meeting's efficiency, as the participants were able to reach a solution and validate it without the need for another meeting.

THE EVALUATION RESULTS

The overall feedback generated from measuring the system's utility, usability and likeability was positive especially in supporting collaborative working, decision making and facilitating meetings' discussions. On the whole, the data generated from the evaluation indicated very positive feedback when the participants were asked to compare their actual experience in using the system with their initial expectation (based on the presentation received in the introduction). The collected data also indicated the participants' high satisfaction with the final design solution they reached in the meeting as a result of the team collaboration together with the group performance and the effective way the system supports of collaborative working by discussing various alternatives and reaching a solution (Figure 4).

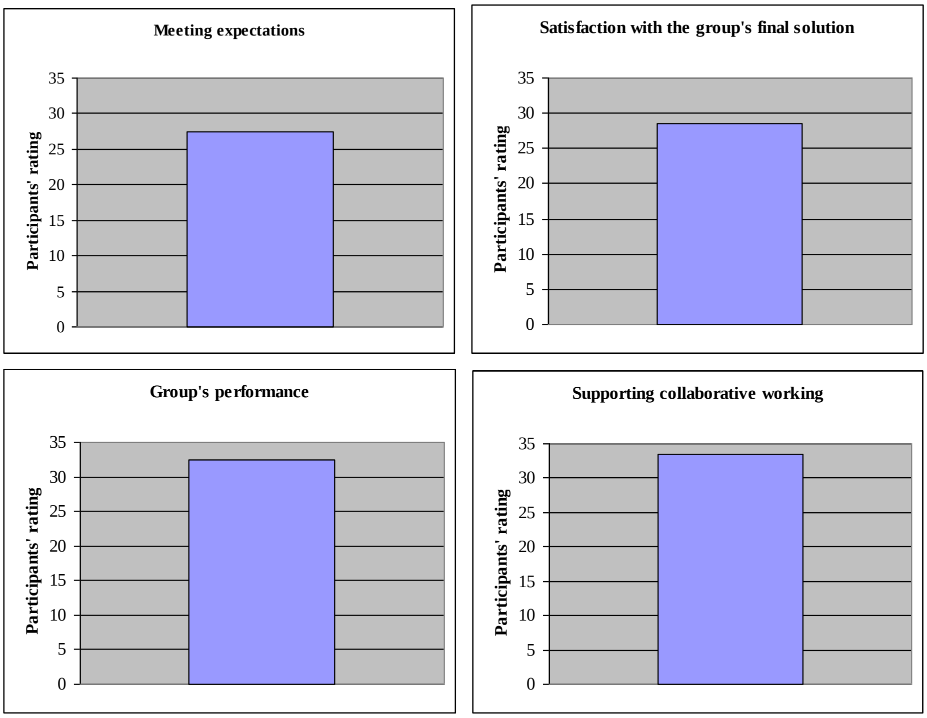

Figure 4- Data representing expectations, satisfaction with the final solution, performance and supporting collaborative working

These above results were confirmed with the overall rate of the CoSpaces system (Figure 5), which indicates how much the participants were in favour of the system and the potential it has to improve the construction industry although some improvement is required but the current prototype demonstrated the capability of a collaborative workspace: “It is evident to me that the system leverages the possibilities in IT in an AEC project context” [end user-COWI].

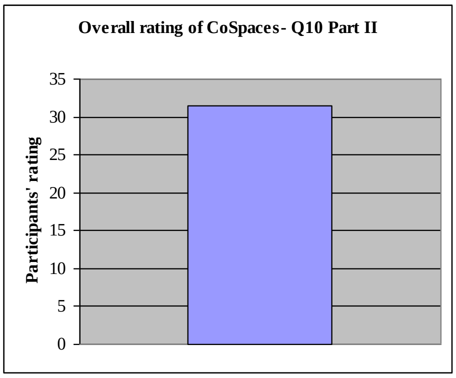

Figure 5- Overall rating of CoSpaces

The following sections explain the evaluation results in detail based on the three key factors used to measure the system.

Measuring the system's utility- (to facilitate collaborative working)

Measuring the system's utility, produced a general consensus among the participants that the system could well be used by design teams to facilitate collaborative design work, improve group's performance as it promotes dynamic interaction, supports decision making, allows exchange of various viewpoints and explores alternative solutions (see Figure 6): "The system helped in supporting the communication with graphical User Interface and simple tools to explain ideas" [end user- COWI]. And it "Provides a collaborative workspace that is managed and allows group members to work collaboratively towards an optimum solution at the same time" [end user- CIT]. Furthermore, some end-users realised the system's potential as a tool for project management.

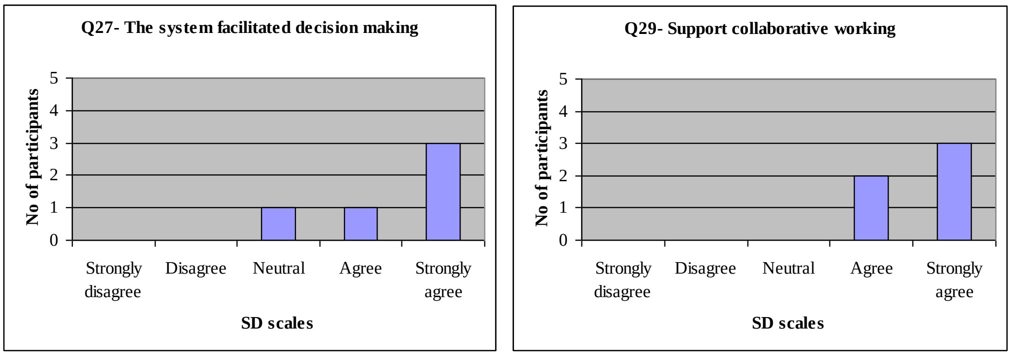

Figure 6- Data representing facilitating decision making and support of collaborative working

Measuring the system's usability- (use of design tools and annotations)

Evaluating the system's usability indicated that, the Co-located workspace application seemed to be quite easy to operate with intuitive tools and annotations (see Figure 7). The participants reported that the system has a clear layers structure and very good quality images. [End user- COWI] claimed that "All group members were enthusiastic and were very fast familiar with the possibilities and the technique". Others found it "Very easy to use to enable collaborative design solution work" [end user- CIT].

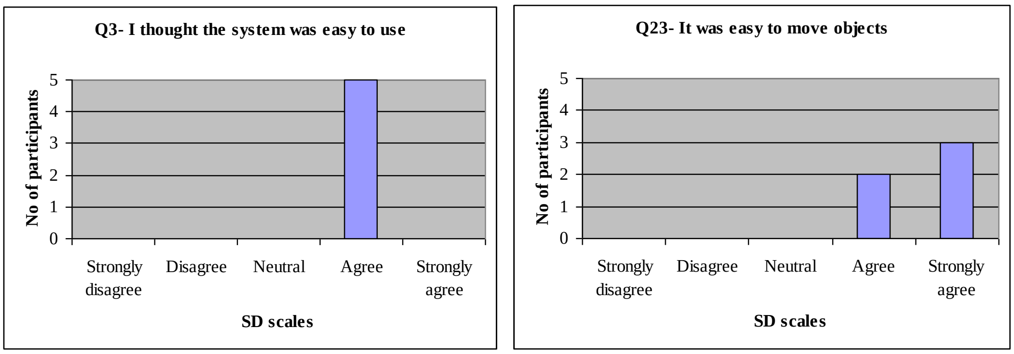

Figure 7– Data representing the easy use of the system and its functions

Measuring the system's likeability

Measuring the system's likeability, user attitudes and experience, highlighted a number of features that the users were in favour of. Examples include the simplicity and ease of use within a very short time with no or very little training required. "Very easy to use after a short period" [end user- CIT]. They also liked the tools and functions (Figure 8) available in the system to create effective real-time collaborative working environment providing them at the same time the freedom to explore many solutions. Other technological features included the possibility to work in a private space, and the real-time track of what people are doing besides the real testing and visualisation of ideas "The system allows decision makers to manipulate and simulate various scenarios during the meeting and make design orders to the back-office by annotations and suggestions without risk of damaging the original model" [end user- COWI].

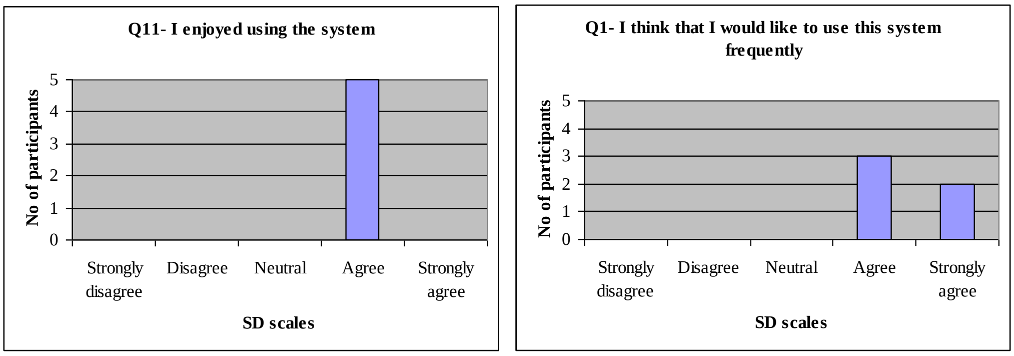

Figure 8– Data representing the well integration of the system's functions

At the same time, discussions with end users during the evaluation generated a number of suggestions to improve the current system's functionality to make it more user-friendly. Since the evaluation took place, the system has been improved to incorporate these suggestions. Cost was raised as an issue by some participants: "To be real effective and to include end users, the system requires a power wall or similar expensive equipment. The size, type and price of the system make it difficult to implement but in large companies and strong organisations" [end user- COWI]. Indeed, cost has always been an issue, however the industry is shifting from thinking of IT investment as being 'cost' endured at a project level to being an 'investment' at an organisational level (Alshawi et al, 2008). In addition, the reduced cost of technological equipment will enable companies to implement it (Fernando, 2008).

CONCLUSION

This paper presented the full implementation together with the evaluation of the CoSpaces platform in futuristic design review scenario in construction. The evaluation results highlighted that the prototype was very well accepted by the CoSpaces end users from CIT (England) and COWI (Denmark). They both stated that the state-of-the-art technologies available in the system provided them with an environment that supports collaborative working and enables them to effectively arrive at an optimum solution to meet the needs of all those involved in the project team.

Improving the system has been an ongoing activity; prioritisation in the following phase includes improving the system's functionality, with the full integration of the portal. The final version of the framework will then be implemented on live projects within the end-users organizations to be followed by another set of evaluation.

In general, the participants agreed that the system performed well providing an impressive set of tools despite the fact that there are a number of issues need to be incorporated into the system. The system facilitated decision making, collaboration and testing a number of alternatives to enable all stakeholders in the project team work together on a construction project sharing the same data at the same time which is the added value of CoSpaces within the co-located scenario.

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