ARTICLE

Collaborative Working – The Elusive Vision

Leela Damodaran and Mark Shelbourn

Abstract

This paper reviews progress towards achieving effective collaborative working in the construction sector. Vision statements published in 1998, 2000 and 2006, which anticipate the envisioned future scenarios in 2010 and 2020, respectively, are examined. The characteristics of these desirable futures are then compared with the current realities as evidenced by seven outline case studies and by the findings of two recent surveys. A considerable gap is identified between the compelling and desirable future visions and current practice. Some of the complex factors responsible for the significant shortfall are identified and discussed. The paper concludes with some recommendations for addressing the shortfall.

■ *Keywords* – Collaborative working; vision; sociotechnical approach

VISION OF COLLABORATIVE WORKING

Recent decades have seen high levels of investment, especially by the European Commission, in research and development projects to generate advanced information and communications technologies (ICTs) for the construction industry. The vision for these and many other related technological developments is that they offer powerful capabilities to the construction sector to enhance performance, reduce waste and improve competitiveness. There is growing recognition that to exploit the potential of ICT-enabled capabilities requires not just implementation of new technologies but the development of new ways of working. These new ways of working involve individuals, often in teams, developing patterns of communication and interaction to enable them to work collaboratively – overcoming the constraints of geography and of time.

DEFINITION OF COLLABORATIVE WORKING

Collaborative working has been defined in a variety of ways. At one end of the spectrum, it is seen as:

> *the creation and use of information, stored within a model, by a project team to enable them to work closely together to achieve benefits such as the efficient development of design solutions, integrated cost planning and installation scheduling, defect-free construction, and so on. (Avanti, 2006)*

ICT from this perspective is seen as:

> *enabling the development and maintenance of a single repository and source of data representing the asset – a 'common data environment' – which contains data that is created with the use of CAD systems, analysis and simulation tools, planning tools, and so on, and input to or extracted from the model through an interface such as an extranet. (Avanti, 2006)*

Further, there is recognition that collaborative working involves more than data transfer: 'Collaboration is more than the ability to transfer data to one another in electronic form. Collaboration is a business process that engages the total project delivery team' (Avanti, 2005). The vision is clear:

Avanti is an approach to collaborative working on projects that enables construction partners to work together effectively. The principles of collaborative working the Avanti way are: early access to all project information by all partners; early involvement of the supply chain; and sharing of project information, drawings and schedules, in an agreed and consistent manner. (Avanti, 2005)

In the mechanistic approach adopted by Avanti, the focus is upon information management and the importance of standardization. Human interactions, social and cognitive activities are not identified as component parts of the collaborative process.

A broader definition of collaborative working offered by Wilkinson (2005) describes it as:

...a creative process undertaken by two or more individuals, sharing their collective skills, expertise, understanding and knowledge [information] in an atmosphere of openness, honesty, trust and mutual respect, to jointly deliver the best solution that meets their common goal.

Where many practitioners in the industry focus on the technological aspects of collaborative working, Wilkinson sees collaboration technology as '...various combinations of software and/or hardware employed to help people collaborate...' and as '...an enabler, a platform that allows collaboration to take place when people are prepared and equipped to do so...'. Wilkinson's acknowledgement of the relevance of human learning, perceptions, feelings and attitudes to the collaboration process is an important step towards a more appropriate definition of collaborative working.

VISION FOR FUTURE USE OF ICT

Recognition of the imperative to establish new ways of working in order to exploit information and communications technologies as collaborative working tools was articulated in 1998. Kikermo and Getty (1998) described their vision for the future as comprising the following elements:

- coordination and alignment of work processes, organizational structures, and technology
- integrated process architecture
- organizational changes to promote collaborative working within teams – teams physically located in the same workspace and assigned to the same team management structure
- deployment of technology to support collaboration and improve work productivity; and
- initiatives for change.

Two years later in the UK, a vision for 2005–2010 was developed by Sarshar *et al* (2000: 2) for 'Construct IT' which is a network of like-minded innovators from organizations in the construction sector (see: http://www.construct-it.org.uk/). This vision was based on the elicited views of members drawn from leading construction companies regarding their future needs for ICT to be used more effectively in the construction sector. From the results of this consultation with the Construct-IT membership, seven major themes were identified as key components of their vision of the future new ways of working as listed below:

- model driven, as opposed to document driven, information management on projects
- life-cycle thinking and seamless transition of information and processes between life-cycle phases
- use of past project knowledge (information) in new developments
- dramatic changes in procurement philosophies, as a result of the Internet
- improved communications at all life-cycle phases, through visualization
- increased opportunities for simulation and what-if analysis; and
- increased capabilities for change management and process improvement in order to realise these themes.

Several of Sarshar *et al*'s (2000) themes reappear in the definition of a vision for the future of ICT in the construction sector as reported by Zarli *et al* (2003) from the ROADCON project funded by the EU:

[The] construction sector is driven by total product life performance and supported by knowledge-intensive and model-based ICT enabling holistic support and decision-making throughout the various business

processes and the whole product life cycle by all stakeholders.

This vision provided a basis for all future research and technology developments (RTD) activities to be funded by the EU in its Framework programmes. A roadmap was developed and describes 12 activities that need to be brought together to enable the vision to become reality (Figure 1).

The 12 activities are crucial components of successful collaborative working but appear to have had little influence over strategic planning for the introduction of collaborative working environments in the construction sector.

Most recently, in 2006, Ballesteros outlined the vision of the European Commission for the Year 2020 – see Table 1 (Ballesteros, 2006a: 33–34).

Although this vision emphasizes the technological aspects of collaborative working, there is also acknowledgement that a considerable range of human, social and organizational features are necessarily an integral part of this vision. For example, in the RTD challenges listed, there is reflected a recognition that the working styles of individuals differ, that there is a need for flexibility, and that collaborative working environments (CWEs) should encompass both social and professional collaboration activities. The explicit reference to such attributes signals an important shift in the focus of ICT developments for collaborative working which will be discussed further in 'Implications of current practice for the future vision of collaborative working' and 'Recommendations' (see below).

CHARACTERISTICS OF NEW WAYS OF WORKING

In his projections, Ballesteros makes an important differentiation between functional and conceptual characteristics of collaborative environments, as shown in Table 2.

This distinction between the functional and conceptual promotes understanding that users require smooth work flow, interfaces that are easy and intuitive to use, and discretion in how they organize themselves and use ICT. Crucially, if innovation is to be promoted, the enabling technologies must permit unanticipated use.

At the First Conference on Collaborative Working Environments for Business and Industry, Dahlsten (2006: 9) also emphasized the need to address cultural, human, social and organizational issues:

Effective collaboration can of course be enabled by technology, but collaboration is not a technology

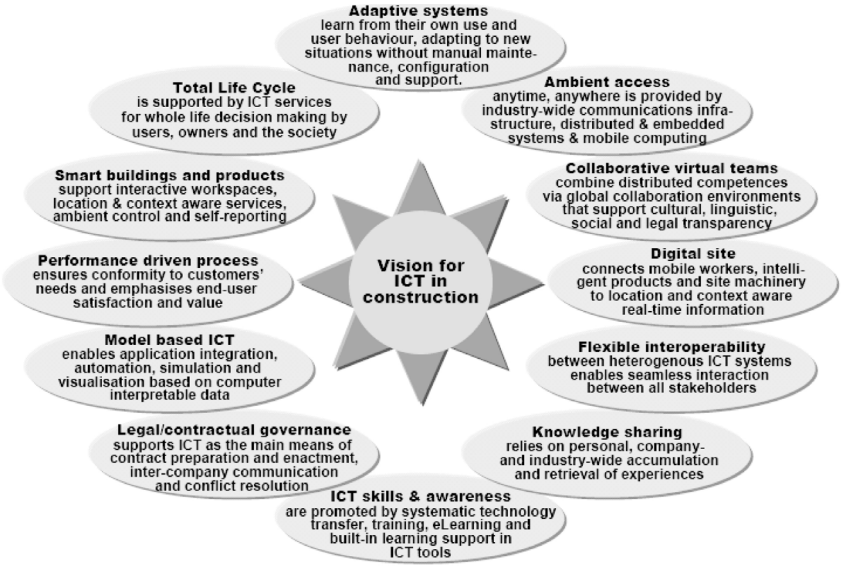

FIGURE 1 The 12 activities of the ROADCON vision (Zarli *et al*, 2003: 35)

TABLE 1 The Vision 2020 for Collaborative Working Environments (Ballesteros, 2006a: 33–34)

THEME	IDEA	RTD CHALLENGE
No more applications-oriented: only resources in activity context and direct interaction patterns (collaboration patterns)	Seamless integration of ideas and experiences Activity context Interaction patterns	Which are relevant collaboration resources? How to determine and confine context of activities, humans, machines and software services? How to 'bundle' collaborative resources and provide offerings?
Service-oriented approach	Collaborative services Integration of synchronous and asynchronous collaborative services	Define fundamental collaboration services How to coordinate loosely coupled collaborative services? How to find collaborative 'resources' and integrate them into CWEs? (e.g. in an ad hoc manner)
Infrastructure and patterns	Collaborative services in infrastructure Interaction patterns Best patterns for collaboration services and their measurement	How to support structuring and work in various team forms (e.g. which team form needs which services)? How to support collaboration patterns? How to provide access and metrics for collaborative services and resources?
Proactive, goal-oriented, culture-aware	Context aware provisioning of collaborative services Support collaborative services for various work styles (e.g. polychronic)	How to build dependable mechanisms for large scale collaboration? How to proactively adapt to changes in context? How to build and provision easily configurable services? Which work styles need to be supported?
Collaborative spaces for work and leisure as well as for social	Collaborative spaces are relevant for work	What are the differences between work and leisure activities needed to be reflected

> *issue per se, it is a people issue. It is about creating the right conditions for effective co-work, and this is as much a cultural issue as a technology one.*

These remarks on the significance of organizational aspects of collaborative working echo those of Kikermo and Getty (1998: 277–283) eight years earlier which appear not to have been heeded in the construction sector.

In a current attempt to counter the emphasis on the technology that prevails in the UK construction sector, researchers at Loughborough University in the Planning and Implementation of Effective Collaborative Working in Construction (PIECC) project have developed a model for effective collaborative working in construction projects that focuses on people and process issues (Shelbourn *et al*, 2006). This model focuses on the organizational and people issues in developing a 'collaboration strategy' so that construction organizations may reap the benefits derived from the use of technology when working collaboratively on construction projects.

The European Commission report (Ballesteros, 2006b: 9) comments on the gap in employees' expectations in relation to the collaboration technologies they experience in the workplace and the collaboration technologies (e.g. mobile phones, laptop computers, and the Internet and its associated services such as instant messaging) that are often used in families, communities and daily personal lives. The gap in the quality of experience and satisfaction gives rise to frustration for employees regarding the limitations of their professional collaboration tools, compared with those they are used to using in their everyday personal life. This report has also noted that there are still improvements to be made to technological aspects of

TABLE 2 Differences between functional and conceptual characteristics (Ballasteros, 2006a)

FUNCTIONAL CHARACTERISTICS	CONCEPTUAL CHARACTERISTICS
Provision of cross-organizational shared workspaces and processes	Natural, multi-modal interaction through the integration of augmented reality (AR) and ubiquitous computing technologies that enable the creation of interconnected distributed work environments
Fully automated document management life-cycles	Adapted to real world situations and new methods of work through bridging structured work flow with unstructured work flow
Support for processing filtering and domain specific visualization of collaboration data	Scalable from small teams to communities to large organizations and from simple activities to complex processes
Fully integrated with desktop management	Supporting transparent organizations to reduce boundaries
Integrating synchronous and asynchronous tools	Pervasive collaboration: anytime/anyplace availability
Scalable from small to large systems across many devices and platforms	Context-based, collaboration-aware, proactive and anticipative to support
Support for quickly finding the right information	Unstructured and multi-threaded collaboration activities and to reduce interruptions
Application of a service-oriented approach to support interoperability, open architectures, and format independence based not only on SOA but also on AJAX – web 2.0 – depending on each use case	Applying social computing concepts to become people- and knowledge-centric, not data-focused
Provision of high bandwidth communication media	Easy and intuitive to use to enable a low cost of entry and use
Provision of virtual dynamic profiles that builds up during use	Enabling the user to determine the way of operation to support self-organization, self-adaptation and self-deployment, thus permitting unanticipated use
Integration of translation tools	Community friendly, adopting some of the characteristics of collaborative games
Context-based collaboration functions	Ready for ageing populations
Personalized and adapted interfaces	
Proper management of personal data	
Supporting data privacy and security	
Support for model standardization	

the collaborative working process (Ballesteros, 2006b: 9). Further it has drawn attention to the reality that the focus of new collaboration tools is on specific and separate tasks without integrating them into a larger work environment and set of inter-related processes. The result reported is a technological lack of interoperability which generates incompatibilities between applications, data and usage patterns – and widespread frustration and dissatisfaction among users.

The vision portrayed by Ballesteros (2006a) foresees the ideal scenario where the needs of the industry and its people are met effectively through the application of ICTs to support collaborative working in construction projects. Such technologies would, for example, provide their users with the ability to simultaneously add and subtract aspects of a building information model – designed in 3D using intelligent building objects – depending on which aspects of the model the individual user requires. If any changes are needed then they can be added to the model with associated changes to other aspects of the model made automatically. If any human interaction is needed, currently available technologies such as mobile phones, handheld PDAs, and laptops can be utilized for this purpose.

This vision for 2020 has much in common with the vision articulated by Kikermo and Getty in 1998. The signs of an emerging realization that the people involved in using construction collaboration technologies are not simply artefacts of the technical systems but are significant in their own right with skills, expectations,

hopes and aspirations is, however, a highly significant change. Thus, users are acknowledged by Ballesteros to be complex human beings with social as well as working lives who have expectations of the technologies that are based upon their experiences in their personal lives:

> *In 2020, collaborative working environments offer a ubiquitous hardware and software infrastructure composed of resources providing a new blend of activity-oriented, context-aware flexible software services supporting patterns of human interactions, human to machine interactions and collaborative gadgets, which all interact in a dynamic and pro-active fashion. (Ballesteros, 2006a: 29)*

Reviewing the four vision statements described above makes very clear the enormous potential benefit that is envisioned to derive from technologies developed to enable collaborative working. In the next section, the reality of current practice in collaborative working practices will be explored to see the extent to which progress towards the vision is being achieved.

THE REALITY OF CURRENT PRACTICE IN COLLABORATIVE WORKING

In order to explore how collaboration tools are being applied in business today, the authors sought a sample of case studies of successful practice for examination. The criteria for selection were threefold:

- the collaboration tools should be in active use
- new ways of working should be in evidence
- there should be tangible (desirably measurable) outcomes.

It had been the intention to discuss exemplars drawn from both the construction sector and from other sectors. However, in the construction sector, case studies that meet all three criteria appear to be in short supply. Consequently, of the seven case study examples outlined below describing collaborative environments introduced into work organizations to improve business processes, five are drawn from sectors other than construction (Stough *et al*, 2000; Fontaine *et al*, 2003; Karlsson, 2006). To complement the case study material, the findings of two surveys of users of collaboration technologies are included:

CASE STUDIES AND SURVEY FINDINGS OF COLLABORATIVE WORKING IN SECTORS OTHER THAN CONSTRUCTION

Sun Microsystems

In 2000, Stough *et al* provided a case description of Sun Microsystems, which has cross-functional virtual teams working to handle customers' orders, enquiries and customer service. Virtual teamworking was seen as a key component in the collaborative working scenario, and essential to achieving the objective of improving productivity. Sun Microsystems developed a system called iWork to incorporate this concept. The system offers choice and flexibility and ultimately allows employees to work anywhere, anytime on any device. In July 2005, Sun Microsystems won a Global Innovation Award for the iWork approach to working, with 13,000 of Sun's 35,000 employees actively using the system. Richert (2006) in a presentation to the First Conference on Collaborative Working Environments for Business and Industry reported that although Sun Microsystems now has over 15,000 employees working in mobile and distributed teams, the management of the company are not confident that this way of working is sufficiently effective. He expressed the view that operational effectiveness can be enabled only with appropriate management support and by the application of new collaborative technologies. The 'appropriate management' support he describes includes the so-called 'soft' issues associated with ICT implementations into organizations. Further reservations were expressed by managers regarding their lack of confidence that distributed teams can be fully effective in the organization. The lack of confidence was seen to be discouraging teams from adopting the new way of working.

Federal Aviation Administration (FAA) Southern Region Disaster Management Team

Fontaine *et al* (2003: 6) reported that the team at FAA have responsibility for keeping 1600 airport facilities running in a region comprised of eight US states (Kentucky, Tennessee, North Carolina, South Carolina, Mississippi, Alabama, Georgia, Florida) and the Caribbean. This requires highly effective management in response to unexpected major events, such as storms, plane crashes or terrorist threats, as well as to more familiar problems such as mechanical malfunctions, faults with radar

equipment or birds nesting in radio towers. Before the advent of ICTs to support collaborative working, the FAA team would sporadically send updates to the regional coordinator, using conference calls and fax. This fragmented delivery of information impeded the capacity of the coordinator to see the whole picture and to evaluate the status of the mission. As a result, the quality of the decision-making and the speed of response were compromised.

To address some of the challenges, in the 1990s, web-based tools were introduced for use by key members of the team to help manage such events. For example, instant messaging and discussion databases to connect experts, the capability to transmit documents, photos and videos, to communicate control schedules, to share information resources and equipment have proved to be helpful and successful applications of collaborative tools.

Within the collaborative environment that has evolved, the teams now send data from the field in diverse formats (e.g. voice, photos, videos, etc.), making the information quickly available to the regional offices and to all the professionals involved. This enables a faster decision-making process and improves the response time to the disruptive event. With the evolution of an appropriate collaborative environment in this way, the evaluation of a complex set of circumstances and the reallocation of resources to solve the problems identified now occurs in a more responsive and timely way.

Montgomery-Watson Harza (MWH)

Montgomery-Watson Harza is one of the world's top three companies engaged in the management of power, water and wastewater. Before using collaborative environments, MWH used face-to-face meetings to carry out project tasks as described by Fontaine *et al* (2003: 8) who characterize the situation as follows:

> *Prior to using CEs [collaborative environments], typical design and build projects at MWH relied on face-to-face meetings. Many design teams had to meet physically in the place where the design work was to be carried out for both key business development and project management tasks. On average, project proposals were researched for weeks in one of four physical MWH project libraries. It was difficult to receive design feedback and comments in real-time, which resulted in design changes occurring 'late in the game'. This method not only required significant travel, but much effort to coordinate and manage projects. On average, project designs took months to complete.*

Significant new ways of working have been introduced which allow the major change in project management arrangements shown in Figure 2 to be realized. The successful introduction of these intra-organizational collaboration practices in MWH has been shown to have shortened the design-to-delivery cycle, increased the quality of service to their clients and reduced the time for completing projects. The design and build project is staffed by designers and a range of construction engineers working in teams in collaborative environments using tools to review and edit 3D design models in real time, to access project documents and to communicate with each other to manage and coordinate projects.

Airbus

From its earliest days, the aeronautical industry has always relied on extensive collaborative effort on the part of a multiplicity of engineers drawn from a range of technical disciplines to design and build aircraft to the high specifications demanded in such a safety-critical application of technology. In recent years, the sector has sought to adopt ICT-enabled collaboration tools and Airbus is seen as one of the successful users of such capabilities. Airbus comprises many partners which have their centres of competence distributed across Europe (Carcasses, 2006). The key task faced by each centre is to equip the people working there to collaborate with partners in other centres with different cultures, a range of different but complementary skills and disciplines in order to work within a common framework, share understanding and access to the same data. This is the challenge to be met by collaboration-enabling technologies within Airbus. Carcasses (2006) describes the collaborative process in the company as follows:

> *The success for an effective collaboration effort depends a lot on the 'human factor'. Of course, the concept of a configured and shared digital mock-up*

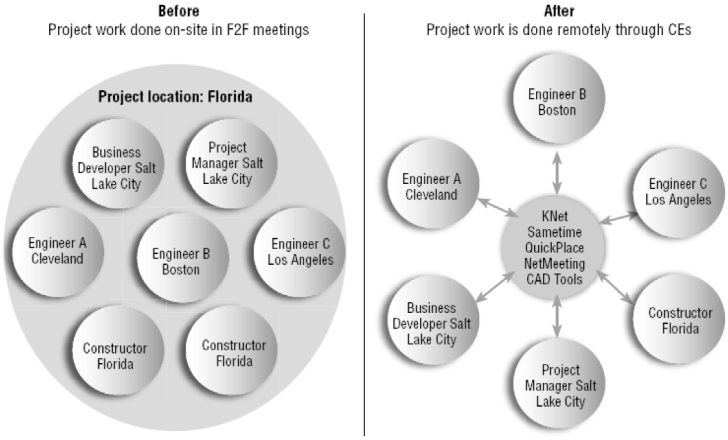

FIGURE 2 Change in project management at MWH as a result of CEs. (Fontaine *et al*, 2003: 8)

(DMU) is necessary. However, the most important aspect has been to organize regular meetings, called 'mock-up reviews' for mid management. These mock-up reviews are organized by CAD/CAM/PDM experts called mock-up integrators.

Their role is to follow-up the different issues raised during the meeting (e.g. a request for a DMU simulation or an ergonomic study, or for missing data or wrong positioning) and support their resolution. Typically, the mock-up integrators are available for any questions outside the meetings.

It is clear from Carcasses's observations that the mock-up integrators and the processes they lead are key human and organizational components of a well-functioning sociotechnical system.

From these experiences of using DMUs, the idea of an Airbus 'virtual shopfloor' has evolved which has three key components:

- the DMU (or product definition master) comprising a very large amount of data which is updated daily and is available everywhere in Airbus
- engagement and connection of a wide range of 'users' including marketing professionals, manufacturing engineers and customer support staff
- an infrastructure designed to be lean, flexible and efficient.

Collaboration between students at Luleå and Stanford Universities

In this study conducted in the education sector, Karlsson (2006: 24) describes the use of collaborative working practices by students at Luleå University who worked in partnership with students in Stanford University: 'Users need to be able to seamlessly move between group and individual work in their every day work. Creative, high-intensity collaboration needs to be supported.' Students at Luleå were involved in an experiment with Stanford University to test distributed brainstorming. The task scenario involved the need to interact with remote physical objects to enable local and remote users to discuss and resolve problems. Such tasks would be necessary for applications such as remote automotive testing in winter to enable test engineers at the proving ground to communicate more efficiently with engineers at the home office. In the experiments, the students shared data in real time and used high-quality video conferencing.

CASE STUDIES AND SURVEY FINDINGS OF COLLABORATIVE WORKING IN THE CONSTRUCTION SECTOR

St Helens and Knowsley Hospital

In this project led by Taylor Woodrow, the opportunities and implications of applying Avanti procedures to support collaborative working were explored through a series of meetings and workshops. The company was seeking to

reduce the waste, cost, time and materials that occur in traditional design processes, and to deliver a design and build project through sharing information in electronic form to produce a coordinated design. In initial meetings, Avanti consultants, Taylor Woodrow personnel and supply chain partners discussed the principles and business case for adopting collaborative technologies. The consultants illustrated the advantages with reference to other projects in which they had been involved. They further indicated areas of benefit that could be expected from making changes to the technology platforms and data standards proposed on the project. The procedures, practices and methods that would be required to achieve the projected benefits were also explained. From this introduction to the Avanti approach, it was agreed that the project team would engage in a process to adopt the new project data standard and management procedures based on the Avanti 'standard methods and procedure' protocol. The next step was to seek 'buy-in' and familiarization of key project team members with the Avanti ideas and methods in a series of one-day workshops.

The workshops raised a variety of concerns among the participants. One key concern related to the timing of this initiative. It was felt that as the project was already underway it would be disruptive, time-consuming and costly to introduce new ways of working at that stage. Another significant concern was the extent of reworking of historical data that would be necessary to reconfigure the project extranet in order to meet the new process management requirements.

Given the scale and depth of concerns voiced by project stakeholders, further meetings ensued to scope the implications of the changes proposed by introducing the Avanti procedures and its associated costs. Avanti consultants also undertook a review of existing processes for sharing and utilizing project data which the team already had in place. This revealed areas of risk for the project which the project team acknowledged and wished to address. The last published reports of the project in March 2006 suggest that with, first, improved understanding of the potential benefits of improved ways of working; second, better planning; third, knowledge of the costs involved; and fourth, identification of the resources (time, effort, reworking, etc.) required to achieve change, there was now a sound basis on which to judge the merits of adopting the new standardized methods offered by Avanti.

Bechtel

The Bechtel company is a multinational construction engineering company with its headquarters in San Francisco, offices in more than 60 countries and clients in 120 countries worldwide. On the Bechtel website (http://software.emc.com/about_us/customer/profiles/bechtel.htm), the challenges the corporation seeks to address are listed as follows:

- Capture intellectual knowledge and business processes in a centralized, easily navigated location while enabling distributed project teams to manage project-specific content.
- Accelerate project completion time by facilitating collaboration among project participants that are geographically dispersed.
- Provide remote web-based access to trusted content.
- Integrate content management system with Bechtel's third-party enterprise and internally developed applications.

To meet these challenges, Bechtel has provided a wide array of capabilities for its engineers, including 3D computer modelling software, high-speed, high-capacity networks which enable staff to work seamlessly with their counterparts in other Bechtel offices. It has implemented the Documentum ECM platform and customized it to meet the company's needs. In addition to its technology implementation, general manager (of the New Delhi Office of Bechtel) Laxman Odedra points out: 'We also align our efforts to ensure that responsibilities and authority are clearly defined.' Further: 'We normally have two, three or four places executing work on the same project, so good communication is crucial ... our people are highly trained and motivated, and they're taught to communicate well through performance-based leadership training.'

The New Delhi office uses a variety of 'globe-shrinking' communication tools, including extensive video conferencing. There's also plenty of face-to-face communication – New Delhi provides construction, field engineering, and start-up support to projects worldwide. 'It helps the project understand our work, and it lets our guys see the results,' says Odedra.

The company asserts that these tools offer the technical and organizational capabilities to:

- Enable project teams to publish and manage content on the web without having to involve IT staff and allow access to this content in a secure, consistent manner by Bechtel and non-Bechtel personnel.
- Provide a highly controlled environment for managing traditional office documents as well as engineering drawings.
- Accelerate and streamline the production, review and approval of data and documents using standard templates and automated work flow tools, available on every desktop.
- Provide a web-based environment to facilitate the exchange of content between Bechtel and its business partners.
- Allow for development of additional content management applications, such as a 'corporate library' for employee access to corporate policies and procedures via a web browser.

The advantages that Bechtel reports have resulted from its use of collaboration technologies are:

- Reduction in the time to complete projects (gained by automating the flow of content according to set business rules and facilitating collaboration among team members).
- Significant time and cost savings to Bechtel and its customers as a result of the ability to publish content to project-based websites without the need for HTML or web development skills.
- Extending the contribution team – Bechtel expects its globally distributed employees to benefit from the collaborative capabilities of the platform, which allows them to work remotely and synchronize when connected to the network.
- Leveraging intellectual capital by maintaining a central repository of information, Bechtel can more easily access and leverage the intellectual capital collected in the 100-plus years of the company's existence.
- Enabling easy integration with other software – the open, standards-based Documentum architecture allows Bechtel to integrate content management with enterprise applications including Oracle and SAP, procurement software, supply chain management systems, Bechtel's portal vendor of choice, and internally developed applications.

Survey of AEC companies in the UK

A survey of 38 architectural, engineering and construction (AEC) companies in the UK was conducted by Yeomans *et al* (2006). The researchers involved characterize these industries as fragmented, with poor knowledge management capabilities, a lack of process transparency and a lack of industry standards.

The investments in IT in these industries have been mainly focused on 3D modelling and collaborative prototyping (CP) with the objective of enabling more efficient collaborative working to occur.

The survey findings show that 26% of the companies participating in the study have tested or actively used CP. However, in the view of the researchers, if the research sample were to be widened to be more representative of the sector as a whole, then they predict that the use of CP would fall into the 0–10% range. The survey findings also show that 61% of the respondents had some understanding and awareness of the collaborative prototyping concept. Of this 61%, more than two-thirds have little or no knowledge about the benefits of using CP.

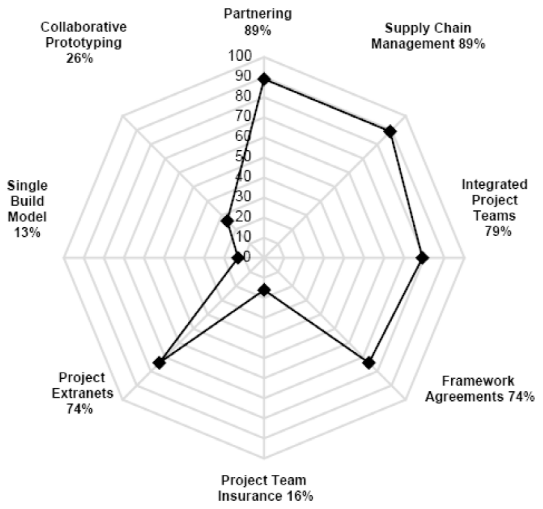

FIGURE 3 Research results showing the percentage of companies and the collaborative working techniques used (Yeomans *et al*, 2006: 146)

Yeomans *et al* (2006) further report a finding, which reflects a consensus among industry experts, that in reality CP is not effective in practice. Their research shows that although companies are keen to give the impression that they are using CP, in reality they are not actually implementing it effectively.

The findings of interviews with experts similarly reflect some doubt regarding the veracity of the success stories reported in the use of collaborative prototyping.

NCCTP survey

The Network for Construction Collaboration Technology Providers (NCCTP) commissioned a survey of customer experiences of collaboration technologies (Network for Construction Collaboration Technology Providers, 2006). The attitudes and experiences of 272 UK-based staff with web-based collaboration systems were explored using telephone interviews. The survey findings indicate that the vast majority (96%) of those who have made active use of collaboration technology 'are happy that it has benefited their business. All these people are likely to reuse the technology on future projects.' Another important finding reported is that:

> *Many commissioning clients (75%) were found to have a distinct preference for working with contractors/suppliers that had experience of using collaboration technology. Supplier/contractors recognize the fact that these preferences exist and believe that their ability to work with such technology is essential if they wish to bid successfully for certain projects with larger clients. (Network for Construction Collaboration Technology Providers, 2006)*

Summary

This section has reviewed the reality of the deployment of collaboration technologies in a variety of contexts. In the next section, the current practices in collaboration revealed in these descriptions will be analysed and discussed.

CHARACTERISTICS OF CURRENT COLLABORATIVE WORKING PRACTICES

The report of the European Commission (Ballesteros, 2006b: 9–22) describing new collaborative working environments supporting business and industries, observes that although there are many sophisticated and advanced collaboration applications available, only a few of them are used and, in fact, e-mail is the application that predominates. Discovering the extent of active use of collaboration technologies is not straightforward given the tendency (noted by Yeomans *et al*, 2006) of companies to exaggerate such usage. The NCCTP survey report notes the considerable variation in the degree of experience that respondents had in using the technology:

> *39% said that they had made use of the collaboration technology on just one or two projects and at the other extreme, 32% had used it on numerous projects. The remaining 29% had used it either on 'just a few' (11%) or 'several' (18%) projects.*

With regard to the tools used to support and enable collaboration, these include web-casts, web-meetings, video and audio conferencing; e-mail and discussion forums; web-based team-rooms and project and document management systems (Ballesteros, 2006b: 9).

From a board-level perspective, Richert (2006: 14–15) commented on his experience in Sun Microsytems in a presentation to the First Conference on Collaborative Working Environments for Business and Industry. He reported that although Sun Microsystems has over 15,000 employees working in mobile and distributed teams, the management of the company are not confident that this way of working is sufficiently effective:

> *Sun's organizations do not yet have the broad capabilities needed to be confident that distributed teams will be as (or more) effective and efficient as co-located teams. As a result, many managers spend effort fighting the reality that teams are, and must be, increasingly distributed. As managers fight this reality, important opportunities to develop the needed capabilities for effective distributed teams are lost. Many of these capabilities can only be developed and learned through experience, which in turn requires management support.*

These insightful observations suggest that the vision of effective and transforming collaborative working practices enabled by advanced technologies has not yet

been communicated adequately or sufficiently widely to be understood and accepted. Certainly the optimism regarding the rapid rate of take-up of collaborative working expected in Fontaine's report in 2003 does not appear to have been borne out in reality: Richert's comments suggest that understanding of the concepts and usage of collaborative technologies are still some way from becoming mainstream processes in Sun Microsystems.

PERCEIVED ADVANTAGES

Emerging evidence suggests that the use of ICT tools to support collaborative working environments has already increased productivity, as envisioned. It has also been observed that 'the growing use of presence tools (MS-Messenger, Skype, ICQ) often has a positive effect of team building in combination with face-to-face meetings' (Ballesteros, 2006a). In particular, the CE enables users to participate in many projects and tasks through:

- increased opportunities to meet in ad hoc meetings
- improved monitoring of collaborative activities
- enabling collaboration with a wider network of people.

The NCCTP survey findings showed that end users of collaboration technologies identified a considerable range of advantages from their usage. For example, 80% of respondents reported 'substantial business benefits' such as access to documents 24/7; a central repository of project management information available to all; reduction in costs due to reduced use of couriers and mail services; more secure deliveries; and an improved audit trail. Furthermore, over 70% are reported to have experienced substantial benefits such as 'better accountability for all parties involved in the project'; 'improved ability to easily find archived information quickly'; and 'an improved audit trail'. In addition, at least two-thirds of all survey respondents reported added benefits including 'greater confidence that everyone is working with the same version of a document' and that 'geographically dispersed teams were enabled to work together on a project much more effectively'. Such user experiences suggest that with the right approach to implementing collaborative working real advantages, consistent with progress towards the vision for 2020, can be realized.

BARRIERS TO ADOPTION

Poor job design

Ballesteros, one of the authors of The European Commission report (Ballesteros, 2006a), suggests that collaboration tools can increase work load and work pressure which he vividly characterizes as: 'users often feel like a "rat in the wheel"'. He also observes that the impact of frequent interruptions on work flow can be deleterious for job satisfaction and performance: 'Collaboration technologies often result in an interrupt-driven work environment, making interruptions a normal occurrence.' For some people, performing some tasks, this disruption in task performance can be a source of stress and may lead to impaired performance. In particular it may be the case that creative thinking and innovation are adversely affected by the reduced opportunities for focused and uninterrupted thought processes, reflection and problem-solving.

Prescriptive nature of current collaboration technologies

The technical focus of ICT design and developments means that the emerging technological tools intended to support collaboration are still prescriptive and often intended to support traditional ways of working. This conflicts with the need to develop new ways of working and with the innovative way in which people actually behave in experimenting with alternative ways of doing things and in problem-solving processes that are part of everyday living. The imposed rigidity and constrained use of collaboration technologies in many construction companies deliver a poor user experience compared with that available in users' personal lives, as noted in the section entitled 'Vision of collaborative working'.

Poor change management practices

The implementation of collaborative environments, as with the introduction of any new applications of ICTs, requires careful management of change. Without this, the introduction of new technology risks turning experienced users back into very inexperienced users.

Best practice in change management has been well researched and documented for many years. Typically, its application ensures that the why, when, what, who and how of introducing change are communicated successfully. Communicating the vision, the benefits of

the new ways of working and giving confidence that there is a practicable plan of action to achieve the stated goals all serve to reduce anxieties about change and curb resistance to it. Despite the widespread knowledge of good practice in change management, it appears that many companies in the construction sector do not routinely apply this knowledge to the implementation of new technologies and instead endure the wastage and high costs of 'rediscovering the wheel'. For example, it appears that in some of the case studies reported, such as St Helens and Knowsley Hospital, there were no transitional arrangements to reduce the day-to-day demands on people while they adjusted to and accommodated a collaborative way of working. A planned migration strategy is well established as an important component of a successful change process. In such a planned migration, extra resources are made available that are tailored to meet the needs of the individuals who face the inevitable 'teething troubles' with the new technology, the take-on of legacy data, the learning and adoption of new procedures and processes and so on. Supporting the transition in this way generally serves to reduce the drop in productivity, and often in morale, that occurs following a major organizational change – making it shorter in duration and not so 'deep'.

Given the neglect of established good practice in change management, coupled with the enormity of the changes required of people to change their thinking, their familiar working patterns, the nature of their relationships with others, and even their values, it is perhaps not surprising that adoption of advanced ICT capabilities – such as collaboration tools – is as limited as the reported findings suggest.

Complexity and constraints of collaborative software applications

Many of the software applications intended to support collaborative working are too complex from the users' perspectives and procedures are not intuitive. The point has already been made that some of the applications compare unfavourably with the 'plug and play' software that many people are readily able to install on their home personal computers. It is also the case that in larger organizations ICT implementations often cause extensive periods of disruption which mean that the performance of day-to-day activities is hampered, thus causing tension, frustration and scepticism about the benefits, value and utility of the new technology. Practical steps, such as those discussed above, to alleviate the pressures during the expected and predictable period of disruption would improve the response to changes introduced and ease the transition.

Lack of 'user friendliness' and undue complexity are becoming increasingly unacceptable to end-users who can now compare the tools they use at work with those they use in their personal lives. The tools they use at work are often found wanting.

EMERGING USER REQUIREMENTS FOR COLLABORATIVE ENVIRONMENTS

The research evidence presented earlier helps to clarify the design requirements of collaboration tools to meet the users' needs for the following:

- seamlessness/ease of use
- flexibility/adaptability
- unanticipated use
- the capability for 'bridging worlds, spaces, objects, contexts and "know-who"' (Karlsson, 2006: 24).

Essentially, users need to be able to move seamlessly between group and individual work in their everyday work intuitively and without conscious effort as part of an enriching and fulfilling experience. To deliver such positive user experiences, the overriding need is for end users to be actively involved in every stage of the design, development and implementation of collaborative technologies (Damodaran and Olphert, 2006).

SUMMARY

The limitations of the current collaborative environments were summarized by the European Commission report (Ballesteros, 2006b: 10), as follows:

> *...the characteristic of current CE is that they are not really integrated and interoperational, that they support mainly point-to-point and not multipoint conferencing, that they are defined mainly for a structured environment providing static artefacts and that they do not support the unstructured orchestration of activities using collaboration-aware objects. Furthermore, they focus primarily on peer communication and not flexible team interaction.*

A further limitation noted relates to poor job design which has resulted in increases in the work load of the users of collaboration technologies and in the number of interruptions encountered in their work. This suggests that, while collaborative working has increased, the impact of the applications on productivity and innovation has been limited, and negative effects such as overload and stress and an unbalanced work–life relationship are also in evidence (Ballesteros, 2006b). The implications of these findings for the future of CE are considered below.

IMPLICATIONS OF CURRENT PRACTICE FOR THE FUTURE VISION OF COLLABORATIVE WORKING

Current practice revealed in the case descriptions and survey findings makes it clear that there is a major shortfall between the potential benefits sought from collaboration technologies and the impact achieved so far. Richert (2006) offers the following analysis of the current state-of-the-art in CE:

> *Distributed team social interactions are highly interdependent with technology enablers. While social interactions are often shaped by available technologies, the main need is for technology to support the social interactions of teams. As technology becomes more capable of accomplishing this support, managers and executives will increasingly accept the 21st century reality of distributed work, triggering a positively reinforcing cycle of: support > distributed team opportunities > new distributed team capabilities > greater team effectiveness > increased support > more distributed team opportunities > more learning > more proven effectiveness and so on. Our immediate objective is to broadly initiate this virtuous cycle.*

In describing his vision for the future of ICT in construction, Richert (2006) shares the insight that:

> *Distance and distributed forms of working are not inherently disadvantageous; they simply represent a new way of work driven by a number of forces, and people need experience with distributed teams to become predictably effective. Thus, the approach to developing the technologies needed to support the social functions of teams should spring from an understanding and encouragement of new ways of work rather than from attempts to mitigate distance or to duplicate the characteristics of face-to-face interactions.*

In relation to ICT-enabled support for teams discussed above, Richert (2006: 14) has pointed out that the most important objective of the technology is to 'support social interactions of teams'. For this to happen, he suggests that the ICTs should be developed to support the new way of working, rather than to merely meet specific and limited objectives such as reducing the effects of geographical separation or providing virtual substitutes for face-to-face interactions. Additionally, the design of these ICTs should be based on research of social interactions and the varied team situations that members can face.

The findings of the EU report (Ballesteros, 2006b: 9–10) make it clear that the vision for collaborative teamwork anticipated by Kikermo and Getty (1998: 277–283) is still a long way from fulfilment. Our analysis of the research into current collaborative working practice (see 'Characteristics of current collaborative working practices') suggests that there are several key reasons for this slow progress, as discussed below.

TECHNICAL FOCUS OF DESIGN AND IMPLEMENTATION OF COLLABORATION TECHNOLOGIES

An engineering approach to ICT design, development and implementation has prevailed for decades. The evidence published in many soundly based studies and analyses on the part of social scientists since the 1950s (Trist and Bamforth, 1951; Mumford, 1983, 1991; Klein, 1976, 2005) and human-factor practitioners (Galer *et al*, 1992) to create awareness of the human, social and organizational aspects of systems has been largely ignored or actively resisted. It appears from the evidence cited in this paper that, at last, there are promising signs that the dominance of the technically focused engineering paradigm may be diminishing.

The case studies and especially the survey findings cited (Yeomans *et al*, 2006) make it clear that implementing collaborative working inevitably involves human and social as well as technical issues. Several of the case descriptions, particularly the FAA Southern Region Disaster Management Team, Airbus and Bechtel,

reveal that the evolving supporting infrastructures for collaborative working are not simply technological ones but, to varying degrees, are also social, human and organizational ones. This is evident from, for example, provision for face-to-face meetings and support for individuals and groups in the performance of their work in ways that suit the task needs of the individuals concerned. In other words, strategies for collaborative working are beginning to take account of at least some of the social, human and organizational needs of the users of the technologies.

Although there is no indication in the reported literature that this is an explicit objective on the part of any of the companies involved, there does appear to be an increase in the level and degree of attention given to designing these social, human and organizational aspects of the collaborative working environment as well as to the technical aspects. This achievement could be accelerated considerably by a proactive application of a sociotechnical approach to the design, development and deployment of improved collaboration technologies (Damodaran and Olphert, 2006).

With improved technologies emerging, it is timely to promote the adoption of such an approach. For example, there is still ample opportunity for Airbus to adopt such an approach and reap the benefits as its deployment roadmap for improved collaboration technologies is still in its infancy (i.e. in the first phase: 2006–2008). Achieving a fast-track route to effective adoption of collaboration technologies would offer significant advantages in enhanced performance, reduced design-to-build time and improved competitiveness.

It is noticeable that despite the emerging good practice in CWEs in other sectors, it is still commonplace in the construction sector for the design and development approach to collaborative technologies to focus on the technical aspects associated with the hardware and software – at the expense of social aspects.

PERSISTENCE OF TRADITIONAL WAYS OF WORKING

Current developments in the application of ICT collaboration tools and methods have not met one of the key prerequisites identified in 1998 by Kikermo and Getty, namely 'that management based on processes and coordination of cycles of activity is a prerequisite for effective collaboration'. Instead, current collaborative solutions reflect, indeed serve to emphasize, traditional ways of working (Ballesteros, 2006b: 9–10). As these conventional ways of working are based on roles and functions, rather than on processes, a fundamental mismatch arises which limits the impact of ICT tools designed to promote collaborative working processes. Applying a sociotechnical approach to work design would offer a powerful means of developing processes well matched to the needs of the users as suggested by the authors above.

TECHNOLOGY PUSH (AS APPOSED TO USER PULL)

The case study of the FAA's Southern Region Disaster Management Team revealed real benefits gained from ICT-enabled collaborative working. Examination of the approach and processes followed suggests that the user-led nature of the development ensured relevance and appropriateness of the collaboration tools selected. First-hand knowledge of their own requirements meant that the future users of the collaborative tools fully recognized the need to enhance human–human communication, to promote flexibility and, perhaps above all, to solve complex real-world problems of a highly safety-critical nature. The participation of the end-users also served to ensure a strong sense of ownership of the chosen collaboration tools – and therefore a vested interest in using them successfully.

LACK OF INVESTMENT IN HUMAN, SOCIAL AND ORGANIZATIONAL ELEMENTS

There is widespread awareness and acceptance that companies have little choice but to invest in the hardware and software elements of ICTs – and these are the major components of cost of such implementations. By contrast, investment in the so-called 'soft' issues, (e.g. communication (especially of future vision) education, leadership training, management of change (including culture change) etc.) is very small indeed. Unless this changes fundamentally, there is unlikely to be significant return on the vast investment in collaboration technologies – and achieving the sought-after vision characterized for collaborative working over the past decade by Kikermo and Getty (1998), Sarshar *et al* (2000), Zarli *et al* (2003) and Ballesteros (2006a) will remain elusive.

RECOMMENDATIONS

For the 2020 vision of widespread adoption of ICT to come to fruition in the context of collaborative working requires major change in the approach to the design, development and implementation of collaborative environments. Key recommendations are the following:

- Design and develop collaborative environments as sociotechnical systems.
- Develop and implement corporate learning strategies to provide learning opportunities for all levels of employees to develop real understanding of collaboration processes and related new ways of working.
- Replace traditional ways of working with new, process-based working methods.
- Introduce a planned strategy for change management based on international best practice.
- Invest in tackling 'soft issues' i.e. in communication, new ways of working, developing trust, and in cooperation.

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AUTHOR CONTACT DETAILS

Leela Damodaran: Department of Information Science, Research School of Informatics, Loughborough University, Loughborough, LE11 3TU, UK. Tel: +44 (0) 1509 635652, fax: +44 (0) 1509 223053, email: l.damodaran@lboro.ac.uk

Mark Shelbourn: Department of Civil and Building Engineering, Loughborough University, Loughborough, LE11 3TU, UK.

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