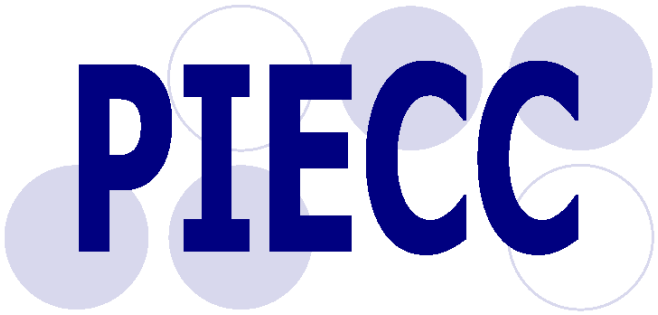
# PLANNING & IMPLEMENTATION OF EFFECTIVE COLLABORATION WITHIN CONSTRUCTION




# ANALYSIS & SYNTHESIS OF LITERATURE

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# Summary

*This document is the accumulation of work carried out in workpackage 1: State-of-the-art review of the PIECC project. The document summarises the key aspects of collaborative working. These include: what is collaboration; definitions; types; information use in; benefits and drawbacks; ICT use in; and the challenges that face collaboration in the construction sector.*

*By bringing this vast amount of information together a discussion of what is required for effective collaboration. Key factors and their interrelationships are discussed. The document then ends with key challenges that still face the construction industry as a whole, and those that will be targeted within the PIECC project.*

## Document Revision Sheet

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| [01] | [Draft] | [All] | [Putting together text and linking it all together.] | 7th March 2005 | MAS |
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# Abbreviations

| | |
|---|---|
| **ALIVE** | Advanced Legal Issues in Virtual Enterprises |
| **COCONET** | Context Aware Collaborative Environments for Next Generation Business Networks |
| **CWS** | Collaborative Work Systems |
| **DIVERCITY** | DIstributed Virtual Workspace for Enhancing Communication within the Construction Industry |
| **ICT** | Information Communication Technologies |
| **ISTforCE** | Intelligent Services and Tools for Concurrent Engineering |
| **IT** | Information Technology |
| **NHS** | National Health Service |
| **OSMOS** | Open System for Inter-enterprise Information Management in Dynamic Virtual Environments |
| **PIECC** | Planning and Implementation of Effective Collaboration within Construction |

# 1. Introduction

"*Collaboration is not a natural way-of-working for everybody!*"

Despite the enormous groundswell of interest in partnering and alliancing in recent years, there has been comparatively little research that has set out to investigate systematically the nature, feasibility, benefits and limitations of forms of project stakeholder collaboration (Bresnen & Marshall, 2000). These forms essentially require effective access to documents and collaboration between project stakeholders to be seen as crucial to the competitiveness of large companies (DeRoure *et al.*, 1998).

For the last two decades, many organizations and individuals have considered electronic collaboration of distributed teams the means of achieving higher productivity and competitiveness and so improving the quality of their work products (COCONET, 2003). One such approach involves a move to working in virtual teams that collaborate across geographical, temporal, cultural and organizational boundaries to achieve global maxima in their organisations outputs. Design teams in particular, therefore increasingly need to make extraordinary efforts to establish and maintain a sense of communication, co-location, coordination and collaboration. Software tools and hardware solutions that support such distributed design teams have therefore become a necessity rather than a fad (Peña-Mora *et al.*, 2000).

Building and construction industry stakeholder collaborations are special in that both the project and the team, and as a result the processes, are potentially unique from project to project (Buckley *et al.*, 1998). These project stakeholder interactions can be facilitated by structuring the virtual work space/environment to create a shared "*landscape of work artefacts*" (Rodden, 1996). Project based applications (Roseman & Greenberg, 1996; Sohlenkamp & Chwelos, 1994) can provide support for the management of personal and shared workspaces and the sharing of work-related artefacts. A notion of shared spaces or "locales" (Fitzpatrick *et al.*, 1996) is also used to structure interactions between interlocators.

A second belief is that for tightly coupled collaborations at least, the creation of a feeling of co-presence between non-collocated collaborators is crucial if computer mediated communication is to be successful. With reference to such communication technologies, Lombard & Ditton (1997) state "*an enhanced sense of presence is central to the use, and therefore the sense of usefulness and profitability of new technologies*". Their argument suggests that a greater sense of presence is correlated with "*a feeling of nonmediation*", and that this should result in a greater quality of interaction.

Negotiation is also seen as a vital part of collaboration (Case & Lu, 1996; Badke-Schuab & Frankenberger, 1999; Peña-Mora & Hussein, 1998; Mentzas, 1996; Sonnenwald, 1996) and computer tools exist that formalise and implement mediation and facilitation techniques to assist in the process. The collaboration-inducing

facilities of ICT are identified as related to their capabilities to support a high-level of interaction, many-to-many communication and information sharing, in a group of known users, across the hierarchical, divisional or time-geographic boundaries (Karsten, ND).

Research has observed that the current collaboration tool landscape is improving but at the same time fragmented, lacking comprehensive solutions (COCONET, 2003). One key aspect is that technology by itself is unable to provide a final answer to the problem of collaboration (Barthelmess, 2003). This may be because cooperative tasks in teams are increasing, and as a consequence the use of collaborative systems is becoming more pervasive (Dustdar & Gall, 2003).

The main sections of the report will discuss the findings from the literature survey in a number of areas. There are sections discussing what collaboration is, work systems, definitions, types, examples, benefits and drawbacks, supportive software and its benefits and drawbacks. These sections provide the basis for a summing up section describing what is 'effective collaboration', and a number of key challenges that are now faced by the PIECC project and the industry as a whole. The next section discusses the meaning of collaboration.

# 2. What is Collaboration?

*Collaboration* is the collective work of two or more individuals where the work is undertaken with a sense of shared purpose and direction that is attentive, responsive, and adaptive to the environment. In collaborative work relationships, the awareness of the environment develops through access to information and knowledge about how work done by a group influences individuals at every layer of context, a process that is often described in terms of effects on stakeholders and customers. Because of this awareness, people who collaborate are able to guide their work so that it meets the needs of those surrounding the work and optimally coordinate their efforts so that their capacity for creating positive change becomes a primary force for generating meaning and commitment.

## 2.1 What is a Collaborative Work System (CWS)

A *collaborative work system* (CWS) is an organizational unit that occurs any time that collaboration takes place, whether it is formal or informal, or occurs intentionally or unintentionally. An intentional focus on CWS requires the conscious and deliberate arrangement of organizational systems aimed at enabling collaboration and limiting impediments to collaborative work. All work groups have elements of collaboration, but intentional focus on CWSs increases and improves collaborative capability. CWSs come in many shapes and sizes. Some forms of CWSs are shown in Table 1.

Collaboration occurs naturally, but organizations tend to create barriers. For example, in traditional functional organizations, often a decision has to be escalated from worker to supervisor to manager in one function, then across to a manager in another function and down to a supervisor to a worker, and so on, before a final decision is made and communicated. The result is a loss of decision-making quality and time. Knocking down functional barriers and allowing workers to talk directly to relevant parties and make their own decisions (when possible) enhances natural collaborative processes and results in better and faster decisions. The goal of an intentional focus on CWSs is individuals and groups effectively working together to achieve strategic goals.

| | |
|---|---|
| Group level | • *Team* – a group of people who have interdependent tasks and a shared purpose and who are held mutually accountable for shared goals<br>• *Community of practice* – an informal group or network of people who have shared interests, stories, and a common language, but are not necessarily held mutually accountable (for example, a group of engineers sharing learning informally) |
| Organisational level | • *Team-based organization* – teams are the unit of work, managers are in teams, and the organization is designed to support teams<br>• *Collaborative organization* – both formal and informal collaboration is supported, teams are used where needed, and the organization is designed to support collaboration |

*Table 1: Examples of forms of Collaborative Work Systems*

## 2.2 Types of Collaborative Work Systems

This section provides one way of defining organisation types. It should be noted that many others have created others. Figure 1 depicts organization types as a function of use of formal and informal collaboration practices. Formal forms include temporary or permanent teams, single or multifunction teams, co-located or distributed teams, and cross-functional or function-specific teams. Informal forms include communities of practice, learning communities, and the "water cooler." Both formal and informal forms depend on structural support and cultural changes, but perhaps to different extents. Ideally, an organization promotes both formal and informal forms becoming what we can be called a collaborative organization.

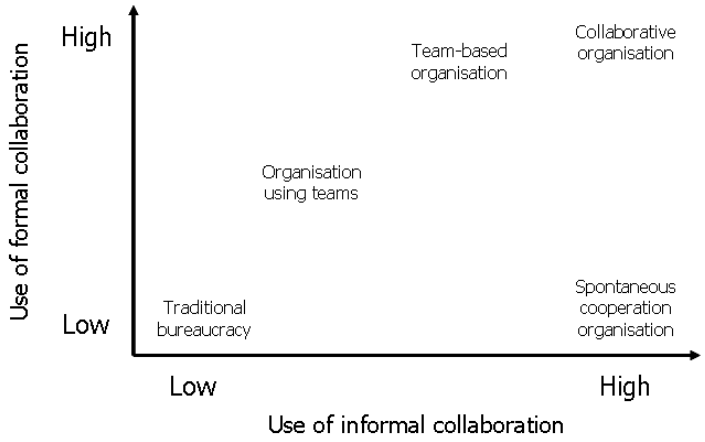


*Figure 1: Organisation types as a function of use of formal and informal collaboration*

Each of the organization types in Figure 1 is described briefly in the table below. See Table 2 & Figure 2 for visual representations.

| Type | Description |
|---|---|
| Traditional bureaucracy | • No teams at any level<br>• Norms, rules, and procedures inhibit informal collaboration (e.g. discussing problems over the water cooler is seen as wasting time and is punishable by the rules<br>• Focus of systems (e.g. rewards and compensation, performance management) is on the individual<br>• Individuals are usually organised in functions (e.g. engineering, production)<br>• High level of hierarchy in reporting structure |
| Organisation using teams | • Some teams used at any level<br>• Norms, rules, and procedures inhibit informal collaboration<br>• Focus of systems is on the individual<br>• Individuals are usually organised in functions<br>• Medium to high level of hierarchy in reporting structure |
| Spontaneous cooperation organisation | • Few to no teams used at any level<br>• Norms, rules and procedures support informal collaboration (e.g. a norm that individuals consult with each other when they need help)<br>• Focus of systems is on the individual<br>• Individuals are usually organized in functions<br>• Medium to low level of hierarchy in reporting structure |
| Team-based organisation | • A variety of team types are used as the basic units of accountability and work; workers and managers are organized in teams<br>• Norms, rules, and procedures do not actively support informal collaboration<br>• Focus of systems is on individual, team, and organization<br>• Teams are usually organized around processes, products, services, or customers<br>• Low level of hierarchy in reporting structure |

| | |
|---|---|
| Collaborative organisation | • A variety of team types are used as the basic units of accountability and work; workers are organized in teams; managers may or may not be organized in teams<br>• Norms, rules, and procedures actively support informal collaboration (e.g. common spaces like lounges are created and employees are encouraged to meet there to discuss issues)<br>• Focus of systems is on individual, team, and organization<br>• Teams and individuals are usually organized around processes, products, services, or customers<br>• Low level of hierarchy in reporting structure |

*Table 2: Organisation types and their ability to collaborate*

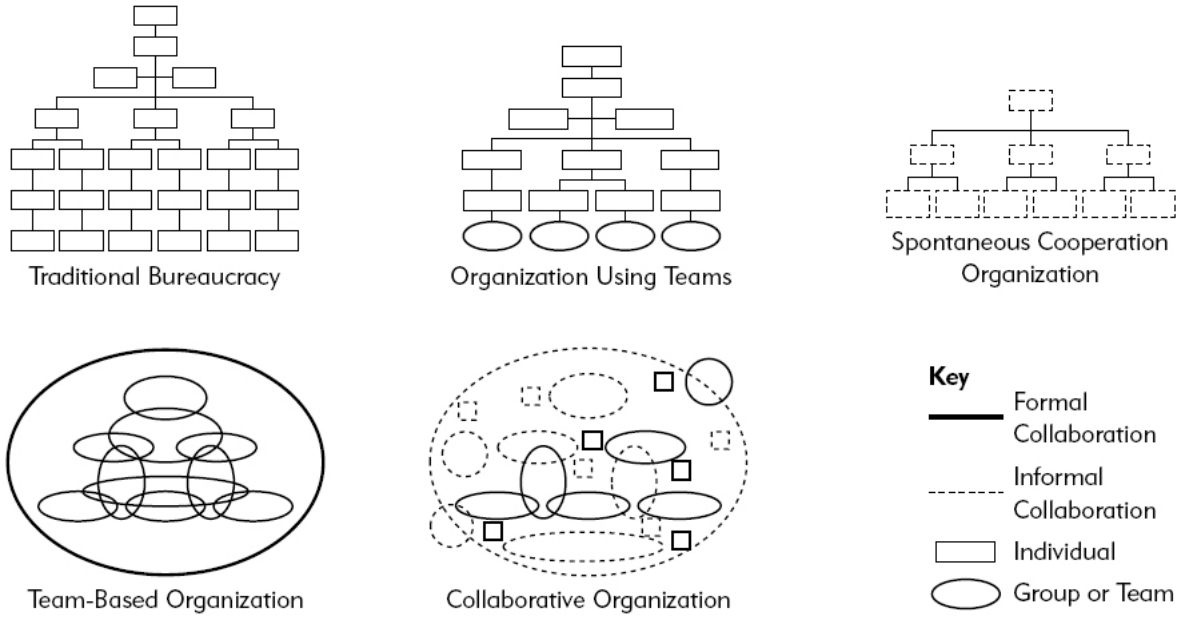


*Figure 2: Visual representations of different organisational collaborations*

There are other organization types that fall in the white spaces of Figure 1. For the sake of simplicity, the types with the most contrasts are shown. Many organisations will fall somewhere between these types.

The literature search has shown that many collaborative work systems (CWS) are defined. The next sections will discuss definitions and types of collaboration.

# 3. Definitions of Collaboration

Many researchers have aimed to define collaboration. Karsten, (ND) defines collaboration "…*as simply to denote communicating and working together across organizational boundaries*…". Others have defined collaboration as: "…*user communication and user awareness of each other's actions*…" (Barthelmess, 2003);

"…*two or more companies working jointly to: share common information; plan based on that shared information; and execute with greater success than when acting independently*…" (Attaran & Attaran, 2002); "…*can be thought of as joint problem solving. It means working with others with shared goals for which the team attempt to find solutions that are satisfying to all concerned*…" (Kvan, 2000); Panitz (1996) sees collaboration as "…*a philosophy of interaction and personal lifestyle and cooperation as a structure of interaction designed to facilitate accomplishment of an end product or goal through people working together in groups*…"; Kvan (2000) and Kvan & Candy (2000) describe collaboration as "…*participants who are committed to a common mission and are willing to share the knowledge that is necessary to fulfil that mission*…". A more formal definition has been provided by German Law, where collaboration is seen as "…*simultaneous and joint will to produce the final result*…" (ALIVE, 2000 - D13 Intellectual and Industrial Property Rights Legal Issues)

From a survey conducted by Mattessich and Monsey (1992) on literature in collaboration, they found that collaboration is often mixed with the words cooperation and / or coordination. Definitions of each of these are:

- *Cooperation* is characterized by informal relationships that exist without a commonly defined mission, structure or effort. Information is shared as needed and authority is retained by each organization so there is virtually no risk. Resources are separate as are rewards.
- *Coordination* is characterized by more formal relationships and understanding of compatible missions. Some planning and division of roles are required, and communication channels are established. Authority still rests with the individual organization, but there is some increased risk to all participants. Resources are available to participants and rewards are mutually acknowledged.
- *Collaboration* connotes a more durable and pervasive relationship. Collaborations being "…*(a) full commitment to a common mission. Authority is determined by the collaborative structure. Risk is much greater*…".

As Mattessich and Monsey emphasize, collaboration requires a greater commitment to a common goal than co-operation with an attendant increase in risk. For this to occur, the level of trust must be higher (Kvan, 2000).

A summary of the definition of collaboration may be taken as: it is activity where a large task is achieved by a team. Often the task is only achievable when the collective resources are assembled. Contributions to the work are negotiated and mediated through communications and sharing of knowledge. Successful collaboration requires effectiveness in a number of areas:

- cognitive synchronisation/reconciliation;
- developing shared meaning;
- developing shared memories;

- negotiation;
- communication of data, knowledge, information;
- planning of activities, tasks, methodologies; and
- management of tasks (Barthelmess, 2003).

Maher *et al.*, (1998) in their experiment in collaborative design, have named three different definitions of collaboration as being:

- **Mutual** collaboration, in which the participants are "…*busy working with the other*…";
- **Exclusive** collaboration, in which the participants "…*work on separate parts of the problem, negotiating occasionally by asking advice from the other*…"; and
- **Dictator** collaboration, where the participants decide who is "…*in charge*…" and that person leads the process.

Belotti and Bly (1996, p.209) have differentiated between local and remote collaboration. They argue that local mobility enhances local collaboration while at the same penalizing remote collaboration severely, since it takes actors away from their desks where their phones and emails are found.

# 4. Types of Collaboration

We have already seen that collaboration requires successful and efficient sharing of knowledge, negotiation, coordination and management of activities (Lang *et al.*, 2002). Anumba *et al.*, (2002) have identified that there are essentially four modes of collaboration depending on the nature of separation and pattern of communication, between the participants in a project, see Figure 3 below.

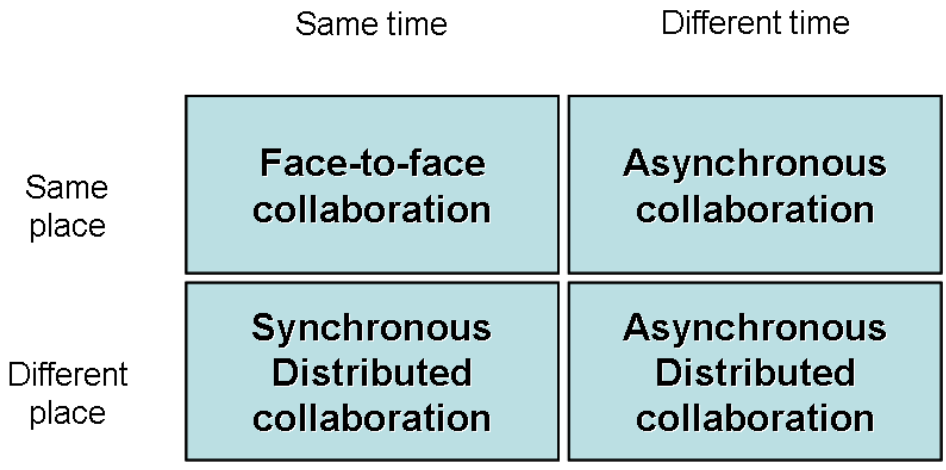


*Figure 3: Different types of collaboration*

- *Face-to-face Collaboration* – this would normally involve meeting in a common venue such as a meeting room, and participants engaging in face-to-face discussions. An example could be an initial face-to-face meeting between an architect and a client for a project brief session. Another example is a meeting between an architect and the structural engineers in order to discuss the implications of a proposed architectural plan on the structural configurations.
- *Asynchronous Collaboration* – this mode of communication can be conducted using such medium as notice / bulletin boards within an organisation.
- *Synchronous Distributed Collaboration* – this would involve real-time communication using any of the current technologies and techniques such as telephones, computer-mediated conferencing, video conferencing, electronic group discussion / editing facilities.
- *Asynchronous Distributed Collaboration* – this mode of communication would involve communications via the post e.g. periodic letters / news bulletins, fax machines, telephone messages, voice mail, pagers, electronic mail transmissions, etc (Anumba *et al*., 2002).

Communication and collaboration will vary on a point-to-point dimension, and a time dimension i.e. the activities that occur may be undertaken on a one-to-one, one-to-many or many-to-one basis, and can be synchronous or asynchronous (May & Carter, 2001).

Most instances of collaboration involve the "…*design*…" of a product, system, service or facility. A certain degree of readiness to tackle collaborative design comes from successes with synthesis and simulation efforts. The technology exists today for the interchange between design and analysis tools to occur in a distributed design environment, a schematic is shown in Figure 4a. Synthesis and simulation can be done in either a tightly coupled architecture or a loosely connected federation. Extending this principle leads to the coordination of individuals communicating with the aid of tools in a heterogeneous environment, Figure 4b. Several of the early demonstrations of collaboration tools can be re-classified as those of coordination (see Mattessich and Monsey, 1992), those that exist for the regulating and refining the design process and its decision-making activities. Figure 4c represents the so called "…*true collaboration*…". In this case, decision-makers coordinate intermittently and when doing so exchange reasoning and experiences to accomplish decision-making tasks. Not all decisions are done real-time by a set of individuals. Often designers will apply lessons learned from decision-making forums during off-line analyses. Similarly, knowledge gained during disciplinary practices are collected and documented and brought to the forum. The end goal is to give rise to better, faster, and cheaper designs through the communication of more than pure analytical results. Ideally, this relationship may be brought to fruition in a mixed human–machine environment in which decision-making occurs, shown in Figure 4d. The challenge is to capture the same reasoning and experience performed in resources in a coordinated environment (Hale & Mavris, 2000).

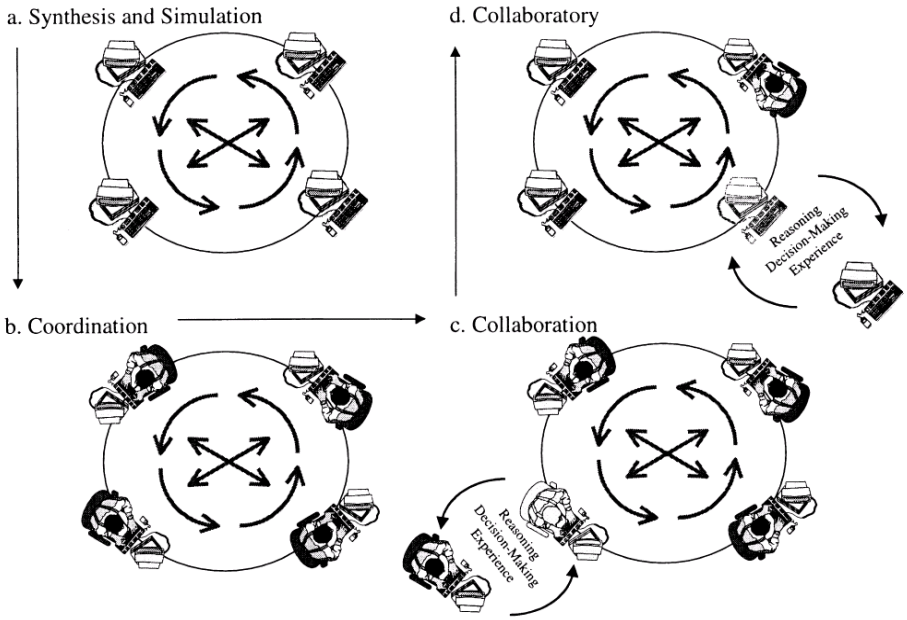


*Figure 4: Types of Collaboration*

Another type of collaboration is the "…*lean-server approach*…". This provides a foundation for Internet-based services and design system access for collaborative design. Examples of such approaches have been demonstrated in a number of EU sponsored research projects. These included: DIVERCITY; OSMOS; and ISTforCE[1]. It enables access to fully-functional design systems and bridges client–server and peer–peer architectures. This approach addresses two fundamental issues of collaboration, namely:

- **Coordination** – promotes the distribution resources throughout an enterprise and manages complex interplay by direct embodiment of a server in the design system.
- **Communication** – monitors communication channels to provide context and content sensitive responses through the use of macros on the open channel (Hale & Mavris, 2000).

Other forms and types of collaboration models have been developed through research and development activities. A model (Figure 5) presented by Bresnen & Marshall (2000) describes how inter-firm collaboration may take place.

[1] Information on these projects can be found at: http://cic.vtt.fi/projects/icci/public.html (last 05/07/2005)

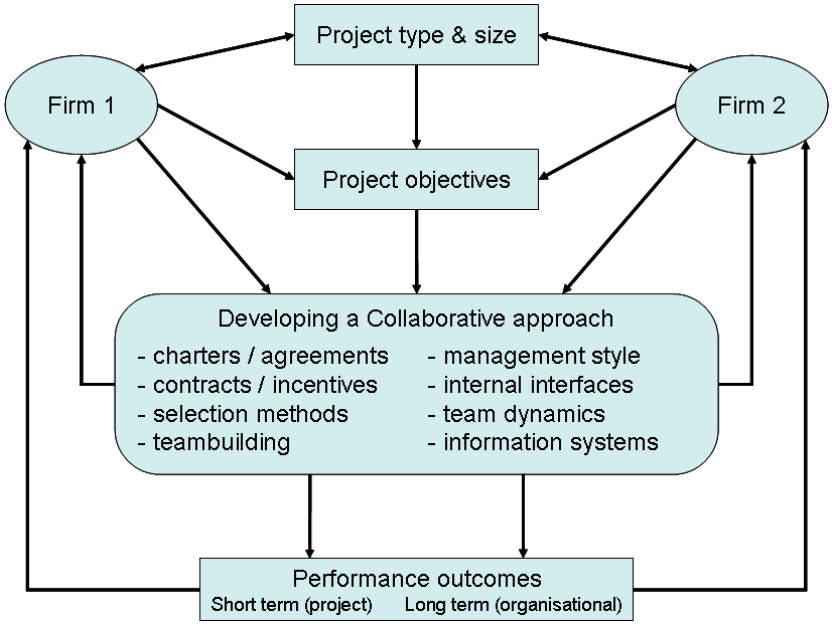


*Figure 5: Inter-firm collaboration as described by Bresnen & Marshall (2000)*

Conner and Finnemore (2003) have provided a model (Figure 6) that shows how virtual teaming can be an effective means of project collaboration.

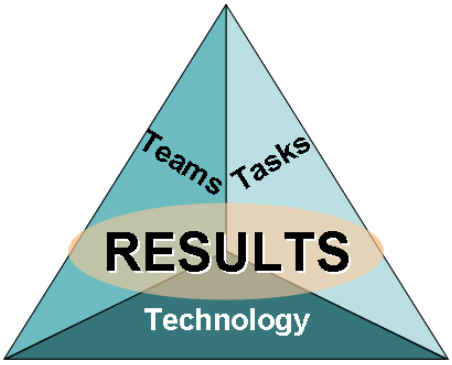


*Figure 6: How virtual teams can be an effective means of collaboration*

The use of visualisation technologies has also be shown to be an effective tool for collaboration. Collaborative visualization involves committed, synergistic efforts among multiple participants using visual displays to frame and address tasks (Brewer *et al.*, 2000). Wood *et al* (1997) proposed that the ideal collaborative visualization systems should support both instructor-driven collaborations and the interaction of multiple independent participants. For the latter, they suggest that the environment should support data exchange, shared control, dynamic interaction, ease of learning, and shared application modes.

Having described definitions and types of collaboration, the next section will describe examples of uses in construction and other industrial sectors such as the National Health Service (NHS).

# 5. Examples of uses of collaboration

Collaborative success has already been defined to be achieved when something has been accomplished in a group which could not have been accomplished by an individual (Kvan, 2000). In the construction sector collaboration in the design process of construction projects is generally regarded to be the critical factor of success (van Leeuwen, 2003).

Collaboration may also be seen to enhance (individual and organisational) learning by encouraging individuals "…*to exercise, verify, solidify and improve their mental models through discussion and information sharing during the problem-solving process (i.e. while working on the assigned group task*)…" (Alavi, 1994, pp. 161-2).

Example use cases of distributed and mobile collaboration include: information updating and notification of availability (of resources); searching and inviting people for diverse synchronous communication (e.g. chat, video/telephone conference); expert search; information retrieval about resources (e.g. users, artefacts, processes); synchronous and asynchronous communication in a community; synchronous collaboration on artefacts (e.g. Groupware); community establishment and updating (Dustdar & Gall, 2003).

Different synchronous and asynchronous means are used: (1) phone and e-mail; (2) Intranet and Lotus Notes; (3) shared network directories; (4) shared work spaces; and (5) videoconferencing are all examples of collaboration tools for construction projects (Dustdar & Gall, 2003).

A survey in 2003 by FACILITATE.COM suggests that audio and web conferencing are the two most popular collaborative meeting technologies. The same survey describes the main uses for collaboration technologies to be:

| **Collaboration technology used for:** | |
|---|---|
| Training | 66% |
| Virtual team / project support | 66% |
| Presentations / web seminars / demonstrations | 65% |
| Strategic planning & decision making | 50-60% |
| R&D, data gathering and requirements definition | 40-45% |
| Customer service | 38% |

*Table 3: Summary of what collaboration technology is used for*

In the NHS, collaboration works just as in many other industries, they share ideas, debate new ways of working and improving services, tapping into expertise just in time, and learning both as an individual and as a team (Conner & Finnemore, 2003). In the integrated manufacturing sector collaboration is seen as requiring participants from many different disciplines to share information and ideas (Harvey & Koubek, 1998).

## 5.1 Information use in Collaboration

Given the wide spectrum of types and levels of detail of information used by various parties involved throughout multiple phases of an AEC project, computer-based collaboration and information sharing appears feasible only in a multi-layered approach. These layers are horizontal as well as vertical, where the latter refers to discipline-specific categories, e.g., architecture and HVAC, and the former pertains to levels of abstractions ranging from low, e.g., textual documents and two-dimensional drawings, to high, e.g., design intent and heuristic rules (Zamanian & Pittman, 1999).

Information sharing and collaboration throughout an AEC project most likely will occur not through a universally accepted standard but by means of multiple protocols suitable for the type and level of detail of information used by certain disciplines at a specific phase of the project. These protocols may range from standardized, multimedia document formats for casual day-to-day communications to more elaborate specifications for parts libraries and project databases. Given this multi-layered approach to information sharing and collaboration, the key challenge still lies in managing the interdependencies among these protocols and their proper usage (Zamanian & Pittman, 1999).

However, many of the long-lasting challenges in AEC information sharing and collaboration, e.g., multiple views of data, representing design intent, versioning, and security, will most likely be addressed in small increments in the coming years as the information technology and the state of computing for the AEC industry mature (Zamanian & Pittman, 1999).

The next two sections will discuss the benefits and drawbacks of working collaboratively.

# 6. Benefits of Collaboration

Various studies have demonstrated that collaboration is beneficial (Doise *et al.*, 1975, 1976; Azmitia, 1988; Ellis *et al.*, 1993). To be successful, a collaborative project must establish a definition of the team, identify their outcomes, ensure there is a purpose of the collaboration and clarify the interdependencies of the members (Kvan, 2000).

Where online collaboration can reduce the need for project meetings, the instantaneous time savings are apparent: where a supplier is located several hundred miles from their customer, a whole day is often required for a meeting that may only last a couple of hours (May & Carter, 2001).

Development engineers from the automotive manufacturers estimated that, on average, about 70% of their time may be spent on activities concerning remotely located suppliers, and as one engineer stated: "…*speeding up the design process is the key, particularly when it concerns collaboration with others*…" (May & Carter, 2001).

Using online synchronous collaboration tools many design and engineering issues can be resolved as and when they arise, due to the reduced time commitment needed from individuals (meetings, with their travel commitments may not be required). This results in a more responsive mode of working. Online collaboration enables the mutual understanding of design issues with input from multiple engineers and designers, while offline activities involve the development of component designs as a result of the collaborative discussions (May & Carter, 2001).

In the FACILITATE.COM survey, between 80-90% of respondents suggested: lowered travel costs, better coordination, reduced cycle time, to be the main benefits of collaborative working. However, the lack of personal interaction (i.e., the ability to see body language, building personal rapport) results in a lower level of trust in both interactions with other people, and the decisions / outcomes of a meeting. It is important to build into project schedules time to build relationships with fellow collaborators. This will begin the process of building trust in the collaboration, an essential ingredient for success in the collaboration.

# 7. Drawbacks of Collaboration

It is clear from the research conducted by Bresnen & Marshall (2000) that people and relationships are considered to be at the heart of collaboration, but that lack of continuity of relationships (at company, team and individual levels) frequently undermines attempts to secure the full benefits of collaboration and to transfer experience across projects. The strategic planning of longer term, mutually beneficial, customer-supplier relationships is needed to realise the benefits of collaboration during concurrent engineering (May & Carter, 2001). These relationships are difficult to achieve and often are more difficult to maintain and sustain.

Although there is a potentially important symbiotic relationship between internal and external processes of collaboration, clearly problems can be caused if project team cultures clash with wider organizational values and norms (Bresnen & Marshall, 2000). This is also seen in the research conducted by Conner and Finnemore (2003) where they stated that "…*accepting the challenge of learning how to work in the*

*different modes, it is clear that finding common time on professional calendars for same time collaboration is more and more challenging as the speed and quantity of work increases…*"

Another drawback highlighted in the literature was actually getting the people to use the tools that make collaboration possible. This is often caused by a combination of different issues: multiple human factors; resistance to change (lack of training, change management processes); limited awareness and lack of management support for the collaboration tools and technologies.

The FACILITATE.COM survey highlighted technical factors (security, access, functionality and IT support) as being the main drawbacks to collaboration, with the most common being an incompatibility between collaboration technologies.

Having described some of the benefits and drawbacks to working collaboratively, the next sections will discuss what effect Information Technology (IT) and Information and Communication Technologies (ICT) has on collaborative working, and some of the software available on the open market, and those at the research and development phases.

# 8. IT & ICT effects on Collaboration

Information technology (IT) and more recently Information Communication Technology (ICT) advances have rapidly changed the ways firms operate their businesses. IT enables firms to redesign business processes, strengthen their customer relationship management, and develop a new business model. Information-intensive business organizations are utilizing IT and ICT to create new knowledge, manage existing knowledge, distribute information, and facilitate inter- and intra-organizational collaboration (Lee, 2004).

It has become accepted practice to use the term "collaborative systems" to describe the computer systems which support distal communication between project stakeholders (Kvan, 2000). All of this technology and different collaborative systems are only support tools to enable collaboration on all levels from human-to-human up to inter-organisational collaboration (COCONET, 2003).

In general, IT and ICT are seen as a collaboration-enabling technology with an inherent model of collaboration, a particular collection of certain facilities or features, by which the technology then enables or constrains collaboration in its own particular way (Karsten, ND). Based on a review of research, Vandenbosch and Ginzberg (1997, p. 68) have identified four conditions, under which the implementation of IT and ICT "…*will enhance*…" collaboration in an organization. Each of these conditions alone is necessary but not sufficient. The conditions are:

(1) organization members need to collaborate;

(2) users understand the technology and how it can support collaboration;

(3) the organization provides appropriate support for the adoption, implementation, and continued use of the technology; and

(4) the organizational culture supports collaboration.

Luff & Heath (1998, p.305-6) lamented the fact that new technologies that promise to provide new spaces and environments for collaboration are only "…*available on devices which are static and tied to the desk*…". The static nature of these technologies entailed the risk of "…*undermining an important resource in collaboration, namely, and individual's ability to reconfigure him or herself with regard to ongoing demands of the activity in which he or she is engaged*…". However this view is now redundant with the introduction of laptops, hand held technologies and sophisticated mobile phones.

There are Internet-based conferencing systems currently available that allow for communication. However, all of them concentrate on the application-to-application side of collaboration and are not specifically geared to handle people-to-people collaboration (Peña-Mora & Hussein, 1998). In particular, there are very few tools available to support distributed asynchronous collaboration (Anumba *et al.*, 2002).

However in a VR environment, changes are handled efficiently by the technology. The ultimate benefit is the ability to create a walk-through, which can facilitate collaboration between clients, designers, contractors and suppliers (Marir *et al.*, 1998; Whyte, 2003). Using such sophisticated technology to support collaboration leads to high-bandwidth demands to support close visual linking in order to replicate co-location (Seward *et al.*, 1993; Harrison & Minneman, 1995; Harrison *et al.*, 1997).

# 9. Collaboration Software

Collaboration software compliments, but does not replace, traditional methods of communication; it is about reducing administrative burden and improving communication. (Compagnia - Collaboration software in the construction industry, June 2003). Collaboration software encompasses intranets, extranets, enterprise portals, knowledge management applications; (Compagnia, 2003).

In order to enable collaboration between different users and to be able to set up so-called virtual teams, a software environment must provide methods for e.g., sharing data between different applications, allowing concurrent access to data, or moving objects through the network (Jasnoch & Haas, 1996).

Attaran & Attaran (2002) have defined a number of technologies that can be used at the four different forms of collaboration described by Anumba *et al.* (2002). See Figure 7.

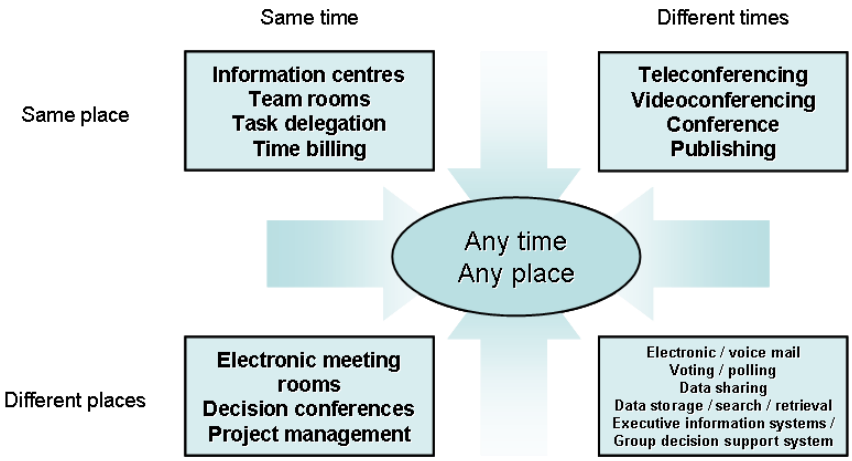


*Figure 7: Technologies to be used at the four types of collaboration*

The measurable savings achieved from the proper deployment of collaboration software comprise an average 1.28% (% of annual revenue or turnover) of measurable direct savings, together with an estimated minimum 3% from measurable consequential benefits. (Compagnia, 2003)

The adoption of collaboration software throughout the construction industry could reduce costs by at least 4.28%, enabling us to build an additional 5 hospitals and 3000 homes per annum without increasing the UK's overall annual construction expenditure of £69 Billion. (Compagnia, 2003)

Currently, a centrally-accessible information system usually consists of a server to which all project members have the option to access and use a common user interface. The common user interface is typically an Internet-based, project team collaboration application developed for document and project management (Sulankivi, 2004)

Audio is absolutely necessary for smooth communication because a video-only solution leads to numerous misunderstandings and communication conflicts, if the users are at distant locations. Additional collaboration tools like text-based chat or shared whiteboards enhance communication or can serve as a substitute if audio is not available.

Visualisation of design models over the Web is one of the effective means to assist co-design. Based on it, design models can be dynamically published in a Web environment and conveniently accessed by remotely distributed groups of people from the management, marketing, maintenance and customers for efficient design collaboration, design process monitoring or product preview (Li *et al.*, 2004)

As a result of the literature survey we can summarise by declaring that collaboration software leads to significant organisational improvements due to the collaborative processes that evolve. The implementation of collaboration software is not without

its risks, but the potential to provide tremendous benefit far outweigh the risks. (Compagnia, 2003).

## 9.1 Benefits of collaboration software

New collaborations based on cost-effective wide area networks and heterogeneous hardware and software platforms, offers the potential for more effective and efficient synchronous and asynchronous communication between virtual team members (May & Carter, 2001).

In the e-process management perspective, giving suppliers access to such systems via the Internet further enhances collaboration. Telecommunication infrastructure (private network) costs in the 1990s made smaller suppliers' collaboration prohibitively expensive. Now, suppliers can participate in design sessions virtually using inexpensive Internet-based collaboration applications. Latest design specifications can be sent to the suppliers for their input using e-mail (Kim & Ramkaran, 2004).

## 9.2 Drawbacks of collaboration software

The key to successful technology supported collaboration does not depend solely upon the technology. It also depends on an organisation's ability to adopt an entirely new way of working. The best technology available will not inherently enhance people's ability to work together. Neither will it improve individual and team productivity, unless the people using it have made a successful behaviour change. In fact, inadequate or inefficient teamwork can be made worse by technology (Conner & Finnemore, 2003).

One of the greatest challenges facing individuals joining a geographically distributed team is isolation. For some people it represents freedom and autonomy as they learn to adapt and flourish in this environment. For most, it is difficult to come to terms with. Our reliance upon face-to-face patterns of collaboration means that when our immediate peers and work colleagues are not face-to-face, we suffer a crisis of work identity (Conner & Finnemore, 2003).

It takes time to build up a relationship and it is often difficult to learn new methods of working in partnership with other firms. Partnerships are often more worthwhile if they are set to last for a long term period, of perhaps five to ten years. However, this time can be well spent earning each other's trust.

Collaboration is time consuming and requires relationship building and is suited to very particular problems that require such close coupling of the design process and its participants. In short, working together, even effectively, is not necessarily collaboration (Kvan, 2000).

Having described many of the issues associated with collaborative working, the next section of the report will bring all this information together to determine what is needed for effective collaboration. It describes 6 key areas for collaboration and the future challenges that are faced by the PIECC project initially, but also the industry as a whole.

# 10. What is needed for Effective Collaboration

To enable an organisation (or organisational unit) to 'effectively collaborate' there must be a harmonisation of three key strategic areas: business, people, and technology.

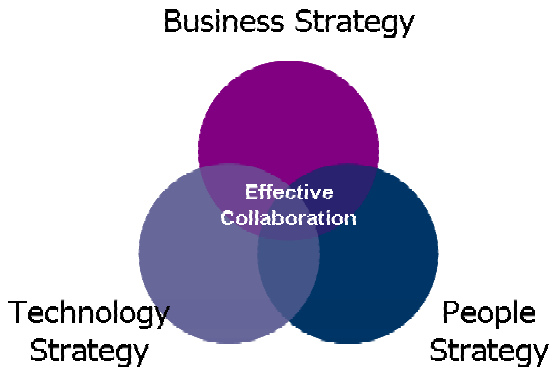


*Figure 8: Key areas for effective collaboration*

Usually collaboration enables participants to build up capacity to complete a set of tasks that one sole organisation would find difficult to achieve. The collaboration eliminates fragmentation, duplication and distrust. This is achieved by intelligently using available resources wisely, sharing the multiple project risk factors across multiple domains, and enhancing staff and organisational motivation. This can only be achieved 'effectively' by bringing together and aligning the three strategic areas of business, people and technology (see Figure 8).

## 10.1 Key areas for collaboration

There are many factors that are likely to influence the success or failure of working collaboratively, many of which have already been discussed in this document. It is important to realise that no two collaborations will progress in exactly the same way or within the same time frame. Each collaboration must find a way to proceed that is consistent with its unique circumstances and composition.

There are 6 key areas that are deemed critical for effective collaboration in construction:

- **Vision** – all members of the collaboration agree on the collaborations aims and objectives;
- (Stakeholder) **Engagement** – collaboration leaders need to ensure that all key participants are consulted as to the practices to be employed during the collaboration;
- **Trust** – time and resources are needed to enable all participants to build trusting relationships;
- **Communication** – a common means of communication is decided by all key participants in the collaboration;
- **Processes** – both business and project, that describe to all key participants how the collaboration is to work on a day-to-day basis;
- **Technologies** – an agreement on those to be used to ensure the collaboration is easily implemented and maintained.

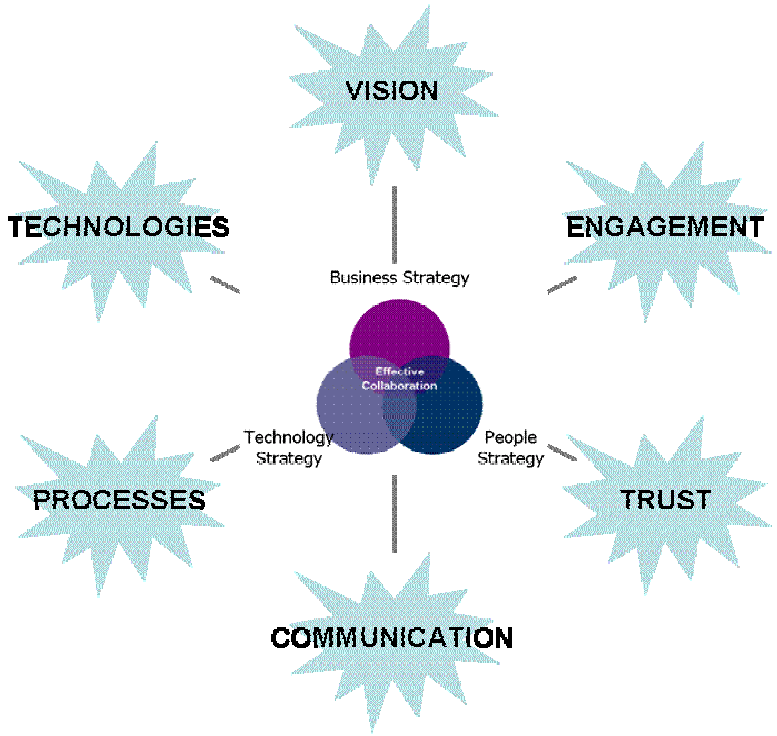


*Figure 9: Areas to be addressed in the strategies to enable effective collaboration*

All 6 areas need to be addressed in the three strategic areas described to have "*effective collaboration*" in the organisation / project context. However, the strategies may be different depending on the context of the proposed collaboration. Differences exist in effective collaboration at the project and organisational level.

Perhaps the most important overarching aspect of effective collaboration is that working collaboratively often means '*new ways of working*' for many / all of the participants involved in the collaboration. Effective collaboration is only achievable through the innovative design and development of a more balanced 'collaboration strategy', that does not rely solely on sophisticated information and communication technologies. As yet there is little evidence of such a 'strategy' existing that prescribes to managers effective ways of implementing and managing collaborative projects / environments. A projected result of the PIECC project is to define this protocol to take advantage of the benefits provided by a more targeted use of information and communication technologies, which are better aligned to the people and business strategies.

Initial findings discussed within this document suggest that it is essential to allow stakeholders to take the necessary time from routine responsibilities to meet and interact with one another so that trust and respect on an individual level can be generated. Personal interactions across the collaborating stakeholder organisations who are attempting to nurture trusting relationships will encounter together the growing pains naturally associated with systemic change associated with the new ways of working. It is worthy of note, that change (i.e. change management principles) begins with individuals, not institutions.

## 10.2 Barriers to effective collaboration

From the comprehensive literature survey discussed in this document some of the barriers to effective collaboration may be summarised as:

- Collaborating organisations have different vision, mission, goals and priorities;
- Organisational 'culture' and methods of communication are often different;
- A lack of focus and consensus on the delegation of tasks;
- An imbalance of resources – time, money, human (frequent turnover of participants) etc;
- Confidentiality, Intellectual Property and legal considerations;
- Technological incompatibility;
- A lack of understanding of the expertise, knowledge and language of the other collaborating participants.

The PIECC projects' aim is to break down these barriers by developing a protocol with associated processes that enables organisations to plan and implement their collaborations in a more effective manner.

# 11. Challenges for Collaboration

The following list provides a summary of the main issues for collaboration found thus far. If we ask the question: Why collaborate? Then the answers are to:

- add value to a project
- be valued as a member of the process
- improve revenue
- improve business planning
- improve Customer Satisfaction
- enhance the Construction industry's image

However, in projects studied by Bresnen & Marshall (2000) collaboration was "…*seen as important, and considerable emphasis was placed upon developing a team culture and fostering the 'right attitudes'*…". It has been shown that these attitudes need to come from top management in the organisation. However, even when collaboration does receive this strong senior management support, there are considerable difficulties reported in diffusing the concept throughout the organization and in translating agreement reached at senior levels into practice (Bresnen & Marshall, 2000).

If we take the AEC industry, many of the industries tasks require collaboration between many partners. Collaboration tasks are complicated by factors such as time and data losses during information exchange, misunderstandings because of ill-defined information, and iterative negotiation when subtask solutions conflict (Lottaz *et al.*, 2000). Also, collaboration may be hindered by the lack of effective and efficient facilities for exchanging and organizing project information (Lottaz *et al.*, 2000). These difficulties are new challenges that research experts need to solve to provide the AEC industry with collaboration tools that they can use in their day-to-day activities, as though they have always used such tools.

One reason that these research issues have lacked sufficient resources is a lack of understanding of the more softer issues of collaboration. It has been argued by Bresnen & Marshall (1998, 1999, 2000a) that frequently research on stakeholder collaboration in construction is often insufficiently informed by the many social science concepts and theories (relating to motivation, teambuilding, organizational culture and the like) that are central to an understanding of cooperation and trust between organizations. Moreover, with many of the organisations involved in construction projects having SME status, if these SMEs are not actively included in agreements to collaborate on projects they perceive stakeholder collaboration as having very little, if any, effect on their own work (Bresnen & Marshall, 2000). It has been argued that if collaboration is to work contractors need established supply chains and suppliers who they work with regularly.

Yet many challenging aspects of collaboration still need to be addressed: coordination; awareness to the contexts of others with the social, ethical and technological aspects of it; translation between different languages; collaboration support in 'collaboration spaces' and multimedia conferencing; and making the collaboration effective by supporting creativity, discourse management and conflict resolution (COCONET, 2003). A possible solution to meet these challenges may be in the offering from a number of research project sponsored in the EU, that include COCONET; DIVERCITY; OSMOS; and ISTforCE[2]. They have realised that since collaboration between different users, belonging to different companies will lead to a large amount of different contexts, all having to be integrated and presented to the user, a context service application should also take care of mapping, translation and integration of different contexts of collaborators (COCONET, 2003). The development of such an application is a major undertaking and should not be taken lightly.

If collaboration is to become widespread in construction then the initiative to change must come from high in the chain, i.e. from the client or contractor and be driven right down to the suppliers. Collaboration partners need to be empowered to locate each other, find experts in required domains and link all coordination information with artefacts such as documents. Therefore the mobility of context (who, what, why, when and using which resources) are essential facets of any collaborative system (Dustdar & Gall, 2003).

Communication remains a weak link for computer-assisted collaboration due to varying standards, platforms and versions of software between organisations (Lang *et al.*, 2002). Also, if clients continue to choose lowest price then collaboration will be difficult to implement. Important factors to consider to cost for collaboration include: how expressive the descriptions of work are; how effective is the distribution among team members; how flexible is the work execution; how much support is available for handling unavoidable variations, among others (Barthelmess, 2003).

To summarize the challenge for developers to enable stakeholder collaboration, is: to enable the building of software systems supporting fully distributed and mobile collaboration requires functionalities currently found in different software application domains such as Workflow Management Systems (WfMS), Groupware, or Business Process modelling tools (Dustdar & Gall, 2003).

# 12. Conclusions

The reality and implications of Collaboration may be summarised as:

- Collaboration is not yet catching on a wide scale. Contractors do not have established supply chains and suppliers are still working on one project at a

[2] Information on these projects can be found at: http://www.cordis.lu/en/home.html (last visited 05/07/2005)

time and usually on a one-off basis. Even those trying to implement change are sometimes still going on lowest price through no fault of their own; if clients continue to go on lowest price then so must the contractor.

- Most still do not have a uniform system for selecting suppliers except by competitive tender, so that that they do not understand the underlying cost base of their suppliers. Industry partners need to be chosen on capability, although they still must demonstrate cost competitiveness.
- Clients need to be brought together to create a bigger buying power to create more work and drive the benefits down the supply chain.
- The client or contractor must have a substantial, continuing workstream that will provide continuity of work to the selected suppliers through a framework contract. From the supply side, there must be a pool of designers, contractors and suppliers who can collaborate with each other and with the client to implement integrated design and construction processes.
- Suppliers must also be able to improve their performance and profits from project to project. We know from previous experience that suppliers say they want to work this way, but have little experience of doing so.

To achieve high efficiency and quality of the collaboration in each construction project, it is essential not only to support the communication processes within the project, but to consider the multi-project work and the individual needs of the players as well (Katranuschkov *et al.*, 2001).

There still remains the tension between automating current collaborative practices and responding to, or driving, process change. One theme of process and IT and ICT improvement and innovation is evident in issues concerned with fundamental redesign or continuous change and improvement. A final theme emerges from the rapid rise of e-commerce which introduces new technological challenges and widely ranging issues regarding business and process implications (Lottaz *et al.*, 2000).

Collaborative tools for distributed meetings and group decision support have not yet achieved widespread adoption, with only audio and web conferencing having large-scale adoption and commonly used functions. Although a variety of factors from cost to management support may be responsible for this, the most common factor is the lack of awareness of what these tools are, what they can do and how or where that can best be applied. For vendors and potential users, education is the key goal!

So while face-to-face collaboration is effective, it is only one way to collaborate and is very limiting when you are trying to achieve collaboration across a group of people (Conner & Finnemore, 2003). Social interaction appears to be the key to collaboration. If there is collaboration then social interaction can be found in it, and vice versa, if there is no social interaction then there is also no real collaboration (Garrison, 1993; Johnson *et al.*, 1985; Soller *et al.*, 1999).

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# References

Alavi, M. (1994) "Computer-mediated collaborative learning: an empirical evaluation", *MIS Quarterly*, Vol. 18 No. 2, pp. 159-74.

Anumba, C.J., Ugwu, O.O., Newnham, L. & Thorpe A. (2002) Collaborative design of structures using intelligent agents. *Automation in Construction*. Vol. 11, pp. 89–103. Elsevier Science

Attaran, M. & Attaran, S. (2002) Collaborative computing technology: the hot new managing tool. *Team Performance Management: An International Journal*. Vol. 8, No. 1/2, pp. 13-20. MCB University Press Limited. ISSN 1352-7592

Azmitia, M. (1988). Peer interaction and problem solving: When are two heads better than one? *Child Development,* Vol. 59, pp. 87-96.

Badke-Schaub, P. & Frankenberger, E. (1999) Analysis of design projects. *Design Studies*. Vol. 20, No. 5, pp. 465–480.

Barthelmess, P. (2003) Collaboration and coordination in process-centered software development environments: a review of the literature. *Information and Software Technology*. Vol. 45, pp. 911–928.

Bellotti, V. & Bly, S. (1996): Walking away from the Desktop Computer: Distributed Collaboration and Mobility in a Product Design Team, in M. S. Ackerman (ed.): *Proceeding of the Conference on Computer Supported Cooperative Work 1996*, pp209-18.

Beyerlein, M. (Ed.). (2002). *Work teams: Past, present, and future.* Hingham, MA: Kluwer.

Beyerlein, M., Freedman, S., McGee, C., & Moran, L. (Eds.). (2002). *Beyond teams: Building the collaborative organization.* San Francisco: Jossey-Bass/Pfeiffer.

Beyerlein, M., & Johnson, D. (Eds.). (1994). *Advances in interdisciplinary studies of work teams: Vol. 1. Theories of self-managing work teams.* Greenwich, CT: JAI Press.

Beyerlein, M., Johnson, D., & Beyerlein, S. (Eds.). (2003). *Advances in interdisciplinary studies of work teams: Vol. 9. Team-based organizing.* London: Elsevier Science.

Bresnen, M. & Marshall, N. (1998) Partnering strategies and organizational cultures in the construction industry, in Hughes, W. (ed.), *Proceedings of the 14th Annual Conference of the Association of Researchers in Construction Management*, pp. 465–476.

Bresnen, M. & Marshall, N. (1999) Achieving customer satisfaction? client–contractor collaboration in the UK construction industry, in Customer Satisfaction: A Focus on Research and Practice, Joint Triennial Symposium of CIB Commissions W55, W65 & W92*,* University of Cape Town, South Africa, 5–10 September.

Bresnen, N. & Marhsall, N. (2000) Building partnerships: case studies of client–contractor collaboration in the UK construction industry. *Construction Management and Economics*. Vol. 18, pp. 819-832. Taylor & Francis Ltd. ISSN 0144-6193

Bresnen, M. & Marshall, N. (2000a) Partnering in construction: a critical review of issues, problems and dilemmas, *Construction Management and Economics*, Vol. **18 No. 2**, pp. 227–37. Taylor Francis Ltd. ISSN 0144-6193

Brewer, I., MacEachren, A.M., Abdo, H., Gundrum, J. & Otto, G., (2000) Collaborative Geographic Visualization: Enabling shared understanding of environmental processes, *IEEE Information Visualization Symposium*. Salt Lake City Utah, Oct. 9-10, 2000, pp. 137-141.

Buckley, E., Zarli, A., Reynolds, C. & Richaud, O. (1998). Business objects in construct IT, *Product & Process Modelling in the Building Industry* (Amor, R., editor), Building Research Establishment, Watford, England, 117-130.

Case, M.P. & Lu, S.C.Y. (1996) Discourse model for collaborative design. *Computer Aided Design* Vol. 28, No. 5, pp. 333–345. Elsevier Science.

Chung P.W.H., Cheung, L., Stader, J., Jarvis, P., Moore, J. & Macintosh, A. (2003) Knowledge-based process management—an approach to handling adaptive workflow. *Knowledge-Based Systems*. Vol. 16, pp. 149–160. Elsevier Science.

COCONET (2003) Research Agenda and Roadmap. Context-Aware Collaborative Environments for Next-Generation Business Networks (COCONET IST-2001-37460). See http:www.europa.net

Conner, M. & Finnemore, P. (2003) Living in the new age: using collaborative digital technology to deliver health care improvement. *International Journal of Health Care Quality Assurance*. Vol. 16, No. 2, pp. 77-86. MCB UP Limited. ISSN 0952-6862

DeRoure, D., Hall, W., Reich, S., Pikrakis, A., Hill, G. & Stairmand, M. (1998) An open framework for collaborative distributed information management. *Computer Networks and ISDN Systems*. Vol. 30, pp. 624-615. Elsevier Science

Doise, W., Mugny, G., & Perret-Clermont, A. (1975) Social interaction and the development of cognitive operations. *European Journal of Social Psychology,* Vol. 5, No. 3, pp. 367-383.

Doise, W., Mugny, G., & Perret-Clermont, A. (1976) Social interaction and cognitive development: Further evidence*. European Journal of Social Psychology,* Vol. 6, pp. 245-247.

Dustdar, S. & Gall, H. (2003) Architectural concerns in distributed and mobile collaborative systems. *Journal of Systems Architecture*. Vol. 49, pp. 457-473. Elsevier Science

Ellis, S., Klahr, D., & Siegler, R. S. (1993) Effects of feedback and collaboration on changes in children's use of mathematical rules. A paper presented in *Society for Research in Child Development*. New Orleans.

Fitzpatrick, G., Kaplan, S. & Mansfield, T. (1996) Physical Spaces, Virtual Places and Social Worlds: A Study of work in the virtual. *Proceedings of CSCW'96, Cambridge*, MA USA, ACM Press, pp. 334-343.

Fülscher, J. & Powell, S. (1999) Anatomy of a process mapping workshop. *Business Process Management Journal*, Vol. 5 No. 3, pp. 208-237.MCB University Press, 1463-7154

Garrison, D. R. (1993). Quality and theory in distance education: theoretical consideration. In D. Keegan (Ed.), *Theoretical principles of distance education*. New York: Routledge

Hale, M.A. & Mavris, D.N. (2000) A lean-server foundation for collaborative design. *Advances in Engineering Software.* Vol.31, pp.679-685, Elsevier Science

Harris, C., & Beyerlein, M. (2003). Team-based organization: Creating an environment for team success. In M. West, K. Smith, & D. Tjosvold (Eds.), *International handbook of organisational teamwork and cooperative working* (pp. 187–209). West Sussex, England: Wiley.

Harrison, S. & Minneman, S.L (1995) Studying collaborative design to build design tools, in: M. Tan, R. Teh Eds., *The Global Design Studio*, CAAD Futures '95, Centre for Advanced Studies in Architecture, National University of Singapore, Singapore, 1995, pp. 687–697.

Harrison, S. Bly, S.A., Anderson, S. & Minneman, S.L. (1997) The media space, in: K.E. Finn, A.J. Sellen, S.B. Wilbur Eds., *Video-Mediated Communication*, Lawrence Erlbaum Associates, Mahwah, NJ, 1997, pp. 273–300.

Harvey, C.M. & Koubek, R.J. (1998) Toward a Model of Distributed Engineering Collaboration. *Proceedings of the 23rd International Conference on Computers and Industrial Engineering.* Vol. 35, No.1-2, pp. 173-176, Pergamon, Elsevier Science

Jasnoch, U. & Haas, S. (1996) A collaborative environment based on distributed object-oriented databases. *Computers in Industry*, Vol. 29, pp. 51-61, Elsevier Science

Karsten, H. (ND) Collaboration and collaborative information technology: what is the nature of their relationship? University of Jyväskylä, Finland

Katranuschkov, P., Scherer,R.J. & Turk, Z. (2001) Intelligent services and tools for concurrent engineering – an approach towards the next generation of collaboration platforms. *ITcon*. Vol. 6. pp. 111-128. Available at: http:www.itcon.org

Kvan, T. (2000) Collaborative design: what is it? *Automation in Construction*. Vol. 9, pp. 409-415. Elsevier Science.

Kvan, T. & Candy, L. (2000) Designing Collaborative Environments for Strategic Knowledge in Design, *Knowledge-Based Systems*, Vol. 13, No.6, pp 429-438. Elsevier Science.

Kim, H.M. & Ramkaran, R. (2004) Best practices in e-business process management – extending a re-engineering framework. *Business Process Management Journal*. Vol. 10 No. 1, pp. 27-43, Emerald Group Publishing Limited, 1463-7154

Lang, S.Y.T., Dickinson, J. Bucha, R.O. (2002) Cognitive factors in design. *Computers in Industry*. Vol. 48, pp. 89–98. Elsevier Science

Lawler, E. E., III. (1996). *From the ground up: Six principles for building the new logic corporation.* San Francisco: Jossey-Bass.

Lawler, E. E., III, Mohrman, S. A., & Ledford, G. E., Jr. (1998). *Strategies for high performance organizations—the CEO report: Employee involvement, TQM, and reengineering programs in Fortune 1000 corporations.* San Francisco: Jossey-Bass.

Lee, I. (2004) Evaluating business process-integrated information technology investment. *Business Process Management Journal*. Vol. 10 No. 2, pp. 214-233, Emerald Group Publishing Limited, 1463-7154

Li, W.D., Fuh, J.Y.H. & Wong, Y.S. (2004) An Internet-enabled integrated system for co-design and concurrent engineering. *Computers in Industry*. Vol. 55, pp.87-103. Elsevier Science

Lombard, M. & Ditton, T. (1997) At the heart of it all: the concept of presence. *Journal of Computer Mediated Communication,* Vol. 3, No. 2.

Lottaz, C., Stouffs, R. & Smith, I. (2000) Increasing understanding during collaboration through advanced representations. *ITcon*. Vol. 5, pp. 1-24. Available at: http:www.itcon.org

Luff, P. & Heath, C. (1998) Mobility in Collaboration, in *Proceeding of the ACM 1998 Conference on Computer Supported Cooperative Work*, pp305-14.

Lytle, W. O. (1998). *Designing a high-performance organization: A guide to the whole-systems approach.* Clark, NJ: Block Petrella Weisbord.

Maher, M.L., Cicognani, A. & Simoff, S.J. (1998) An experimental study of computer mediated collaborative design. *International Journal of Design Computing*. Vol. 1. 1998.

Marir, F., Aouad, G. & Cooper, G.S. (1998) OSCONCAD: A Model-based CAD system integrated with computer applications. *ITcon*. Vol. 3, pp. 25-44. Available at: http:www.itcon.org

Mattessich, P.W. & Monsey, B.R. (1992) *Collaboration: What Makes It Work?* Amherst H. Wilder Foundation, St. Paul, MN, 1992.

May, A. & Carter, C. (2001) A case study of virtual team working in the European automotive industry. *International Journal of Industrial Ergonomics*. Vol. 27, pp. 171-186, Elsevier Science

Mentzas, G.N. (1996) Team coordination in decision support projects. *European Journal of Operational Research* Vol. 89, pp. 70–85.

Miles, R. E., Coleman, H. J., Jr., & Creed, W. E. (1995). Keys to success in corporate redesign. *California Management Review, 37,* 128–145.

Mohrman, S. A., Cohen, S. G., & Mohrman, A. M., Jr. (1995). *Designing team-based organizations: New forms for knowledge work.* San Francisco: Jossey-Bass.

Orsburn, J. D., & Moran, L. (2000). *The new self-directed work teams: Mastering the challenge.* (2nd ed.). New York: McGraw-Hill.

Panitz, T. (1996). *Collaborative versus cooperative learning*. Available from http://www.city.londonmet.ac.uk/deliberations/collab.learning/panitz2.html [accessed 15th February 2005].

Pasmore, W. A. (1988). *Designing effective organizations: The sociotechnical systems perspective.* Hoboken, NJ: Wiley.

Peña-Mora, F., & Hussein, K.M. (1998) Proactive meeting management for distributed collaborative design. *Advances in Engineering Software*. Vol. 29, No. 10, pp. 839-849. Elsevier Science Ltd

Peña-Mora, F., Hussein, K., Vadhavkar, S. & Benjamin, K. (2000) CAIRO: a concurrent engineering meeting environment for virtual design teams. *Artificial Intelligence in Engineering*. Vol. 14, pp. 203-219. Elsevier Science.

Purser, R. E., & Cabana, S. (1998). *The self-managing organization: How leading companies are transforming the work of teams for real impact.* New York: The Free Press.

Ray, D., & Bronstein, H. (1995). *Teaming up: Making the transition to a self-directed, team-based organization.* New York: McGraw-Hill

Rodden, T. (1996) Populating the Application: A model of Awareness for Cooperative Applications. *Proceedings of CSCW'96*, Cambridge, MA, USA.

Roseman, M. & Greenberg, S. (1996) TeamRooms: Network places for collaboration. *Proceedings of CSCW '96*, Cambridge, MA, USA.

Seward, R., Diaper, D. & Sanger, C. (1993) The pod: a purpose-built environment to support group working, in: D. Diaper, C. Sanger Eds., *CSCW in Practice: An introduction and case studies*, Springer-Verlag, London, pp. 151–162

Sohlenkamp, M. & Chwelos, G. (1994) Integrating Communication, Cooperation and Awareness: The DIVA Virtual Office Environment. *Proceedings of CSCW'94,* Chapel Hill, NC, USA.

Sonnenwald, D.H. (1996) Communication roles that support collaboration during the design process. *Design Studies*. Vol. 17, pp. 277–301.

Sulankivi, K. (2004) Benefits of centralised digital information management in multipartner projects. *ITcon*. Vol. 9, pp. 35-63. Available at: http:www.itcon.org

Vandenbosch, B., & Ginzberg, M. (1997) Lotus Notes and Collaboration: Le plus ca change, *Journal of Management Information Systems,* Vol. 13, No. 3, pp. 65-81.

van Leeuwen, J.P. (2003) Computer Support for Collaborative Work in the Construction Industry. In: Cha, Gonçalves and Steiger-Garção, *Proceedings of the International Conference on Concurrent Engineering*, Madeira, Portugal, July 26 – 30, 2003, Balkema Publishers, pp. 599-606.

Westwater, M.G. & Johnson, G.I. (1997) Comparing heuristic, user-centred and checklist-based evaluation approaches. In: Robertson, S.A. (Ed.), *Contemporary Ergonomics*. Taylor & Francis, London.

Whyte, J. (2003) Industrial applications of virtual reality in architecture and construction. *ITcon*. Vol. 8, pp. 43-50. Available at: http:www.itcon.org

Wood, J., Wright, H. & Brodlie, K., (1997) Collaborative Visualization, Proc., *IEEE Information Visualization '97*. IEEEComputer Society, Pheoniz, Oct. 19-24, 1997, pp. 253-259.

Zamanian, M.K. & Pittman, J.H (1999) A software industry perspective on AEC information models for distributed collaboration. *Automation in Construction*. Vol. 8, pp. 237-248. Elsevier Science