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Edited by
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Collaborative Construction Information Management

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Introduction

Collaborative construction information management – evolution and revolution

Andrew Baldwin, Geoffrey Qiping Shen and Peter Brandon

The aim of this book is to explore the way in which construction information management has the power to make the construction industry more effective and efficient. In particular it considers the growing interdependence between the participants in the process and their changing roles as they harness the power of the new technologies in new collaborative arrangements. It is not solely about technology, although this is the facilitator of change, but the manner in which behaviour will change as collaboration and communication are enhanced.

Introduction

The inefficiencies and low productivity of the construction industry are well documented. Despite the emergence and adoption of information and communication technologies to assist both design and construction the industry's productivity remains low. Compared to other industries, productivity in the US construction industry since 1964 has decreased (Li *et al.* 2008). Why? The construction industry is highly fragmented, it is dominated by small and medium-sized organisations, and in a typical construction project there are a large number of participant organisations. Communication and information exchange problems proliferate, and it is widely accepted that to overcome productivity problems construction organisations need to work collaboratively. How best can this be achieved?

In 1984, Irene Greif of MIT and Paul Cashman of Digital Equipment Cooperation organised a workshop attended by individuals interested in using technology to support people in their work. The workshop covered different industries. During this workshop, the term 'computer-supported cooperative work' (CSCW) was first coined to describe work supported by computer technology (Grudin 1994). Since then the word 'collaborative' has normally replaced 'cooperative', and 'computer-supported collaborative work' is the generally accepted term. This term recognises the importance of the computing, information and communication technologies to facilitate collaboration in construction.

Since 1984 there has been considerable research into the evolution of CSCW. This has focused on both the development of the supporting technologies and the human and organisational aspects of their adoption. Terms such as 'concurrent engineering' and 'groupware' have emerged together with others to describe collaborative working in a computer-supported working environment. This therefore is the topic of our book.

Collaboration is a highly complex and challenging task, which can be defined as 'The agreement among stakeholders to share their abilities in a particular process, and to achieve the objectives of the project as a whole' (Kalay 1998).

Collaborative working in construction means joint efforts among project stakeholders to effectively and efficiently accomplish a construction project. Collaborative working covers a spectrum of ways that two or more organisations can work together. Options range from informal networks, alliances or partnering to full integration. It can last for a fixed length of time or can form a permanent arrangement.

Collaborative construction information management represents a research area which focuses on a collaborative, integrative and multidisciplinary team of stakeholders tackling complex multi-scale issues involved in creating viable solutions in the context of the built environment.

Recent reports highlight the importance of collaborative working both now and in the future. It is argued that in the constantly changing global economy

> the ability to communicate over time and space, within and between organisations or communities, is essential to achieve this flexibility by making the best use of the knowledge and competencies available. Furthermore, collaborative environments are necessary to increase the productivity as well as the creativity by enabling new forms of work in production and knowledge intensive businesses.
>
> (European Commission Information Society and Media 2006)

In *The Future Workspaces*, a book providing insights into the findings of a major EU research project which looked at perspectives of mobile and collaborative working (Scaffers *et al.* 2006), the authors consider our places of work and reflect that these are in a transition and that 'the way in which we are organising our work has changed considerably over the past 20 years and will continue to do so in the future'. They provide a detailed vision regarding characteristics of mobility and future ways of working. This is summarised in Table I.1. Importantly they stress that this 'workplace innovation' 'is not just a matter of technology alone. Among the key issues are: workplace organisation, regulations, cross-organisational cooperation, management and leadership, organisational structure, business models, and incentive schemes.' The Future Workplace Study covers a range of industry

Table I.1 Mobility: traditional view and MOSAIC vision

	Traditional view	*MOSAIC vision*
Mobility concept	Mobility of the individual via forms such as teleworking and working on the move.	Mobility of both individuals and collaborating teams, work and workspaces.
Thrust	Support of mobile working within existing process boundaries.	Undertake work at the place and time according to need.
Values	Individualism, organisational efficiency and benefits.	Work–life balance, sustainable development, societal benefits.
Work environment	Individual workplace supporting people on the move at different locations in carrying out their work.	Collaborative virtual workspaces adapting to context and enabling work to be carried out anytime, anywhere.
Work	Work mostly oriented to communication activities and access to information.	Work oriented to all primary and secondary aspects of work and to collaborative working.

Source: Adapted from Scaffers *et al.* (2006).

environments including engineering. We share these visions and perspectives for collaborative working in construction.

We believe that the emergence of building information modelling (BIM), together with related technologies (such as virtual prototyping), represents a new way of working that will become widely adopted throughout the construction industry over the next 15–20 years. These new technologies, first introduced and subsequently developed by leading architects such as Frank Gehry, are now being embraced by numerous clients, designers and construction organisations worldwide. The adoption of this way of working and the benefits that may be accrued when it is adopted offer a new platform for information management and a new basis for collaborative working. These technologies have the potential to revolutionise the construction industry and enhance collaborative working. To achieve this, collaborative construction information management will be crucial.

This chapter reviews collaborative working and related technologies. It identifies the key aspects of BIM and related technologies currently available to facilitate collaborative working and highlights the contributions of the leading researchers and industry members who have contributed to this book. These contributors see BIM and related collaborative technologies as a platform for the emergence of a new form of collaboration that will inevitably lead to changes in the traditional roles of the participants within construction projects. Issues relating to information management are highlighted. As with the emergence of all new technologies their rate of diffusion and adoption throughout the industry cannot be assured. The contributors also discuss inhibitors to change and how these may be overcome.

Collaborative working

Collaborative working in the modern context may be considered to have commenced with the advent of computing technologies. One of the originators of the term 'computer-supported cooperative working' (CSCW), Irene Greif, commented that they coined the phrase partly as a shorthand way of referring to a set of concerns about supporting multiple individuals working together with computer systems. 'The meanings of individual words in the term were not especially highlighted' (Greif 1988). Since then different researchers have proposed alternatives to the word 'cooperative'. Cooperative working, or coordinated working, or collaborative working? What is clear is that even from the outset the focus was on 'presenting and discussing research and development achievements concerning the use of computer technologies to support collaborative activities, as well as the impact of digital collaboration technologies on users, groups, organizations and society' (Greif 1988).

Collaboration is widely interpreted as working in unison. Collaboration is more than working in an informal relationship or on a compatible mission; it denotes a more durable and persuasive relationship. Collaboration includes 'user communication and user awareness of each other's actions' (Shelbourn 2005). It is 'two or more companies working jointly to: share common information; plan their work content based on that shared information; and execute with greater success than when acting independently' (Barthelmess 2003). Collaboration may be seen 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' (Attaran and Attaran 2002).

In his study of collaborative working Grudin (1994) commented that CSCW started as an effort by technologists to learn from economists, social psychologists, anthropologists, organisational theorists, educators and anyone else who could shed light on group activity and that CSCW should contain two main concerns: the technology used to support people's work and how people work in this technology-supported environment. The authors concur and use the word 'collaboration' in all considerations, as we consider collaboration to include all aspects of technology, organisation, process and human factors, and emphasise the need for a holistic perspective.

Modes of collaborative working

The advent of modern computing technologies has resulted in different modes of collaborative working. Understanding and solving the main issues presented by collaborative working depend on conceptualising how people work (Palmer and Fields 1994). Anumba *et al.* (2002) describe modes of collaboration based on a classification of space and time. These are shown in Figure I.1. Typical forms of collaboration in space and time are also described by Attaran and Attaran (2002) and Baecker *et al.* (1995). The types of communication shown in Figure I.1 are discussed by Ugwu *et al.* (2001) and summarised below.

Face-to-face collaboration (synchronous mode) normally involves meeting in a common venue such as a meeting room, and participants engaging in face-to-face discussions. An example of this type of collaboration is a meeting between an architect and the structural engineers to discuss the implications of changes to the layout of a building. Face-to-face collaboration may also involve participants working at the same time in the same room on activities ranging from group decision making to group authoring or running a CAD program (see Palmer and Fields 1994).

Asynchronous collaboration means that activities take place at different times but in the same location. This mode of communication can be conducted using media such as notice or bulletin boards within an organisation.

Synchronous distributed collaboration involves activities that take place at the same time but where the participants are located at different sites. This involves real-time communication using one or any of a range of the current

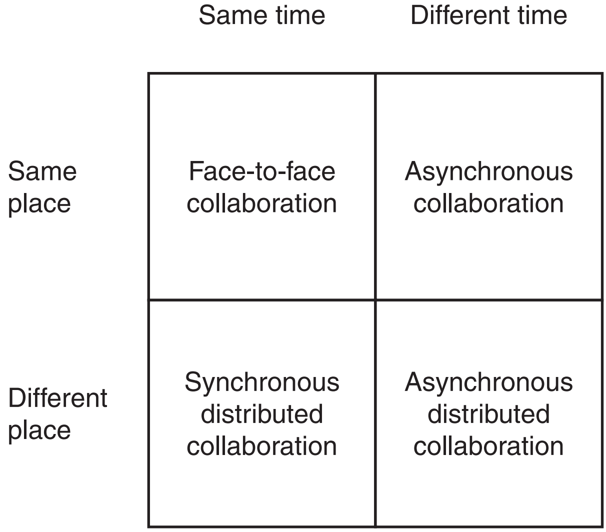

Figure I.1 Collaboration models.

Source: See Anumba *et al.* (2002).

technologies and techniques such as telephones, computer-mediated conferencing, video conferencing, electronic group discussion or editing facilities and so on.

Asynchronous distributed collaboration is where activities take place at different sites at different times. This mode of communication involves communication via the post, for example periodic letters or news bulletins, fax machines, teletex, voicemail, pagers, electronic mail transmissions and so on.

Whatever mode of communication is adopted between the parties within the project it is essential that all parties are provided with updated, accurate information on which to base their decisions. Since its inception collaboration has been facilitated by different technologies. These technologies have changed as new technologies have emerged to supplement and replace those that already exist. This evolution is now examined.

Evolution

The last 25 years have seen considerable growth in the power and applicability of computers. This has dramatically increased the usefulness of digital electronics in nearly every segment of the world economy. Moore's Law, the name given to the findings of Gordon Moore, who noted that the number of transistors that can be inexpensively placed on an integrated circuit increased exponentially, doubling approximately every two years, describes the historical trend for computing power to increase exponentially (Moore 1965; Intel Corporation 2005). Similar increases in performance have been achieved with respect to computing performance per unit cost; power consumption; hard disk storage cost per unit of information; and so on.

Alongside this background of advances in computing power there have been considerable advances in software technology. The types of user interfaces between computers and system users have now consolidated, and de facto standards, for example for web-based systems, have emerged. East *et al.* (2004) conducted an in-depth analysis of the impact of web collaboration and conclude it is a very effective medium for conducting design reviews and offers many benefits over traditional manual methods of comment collection and resolution. There are a number of software developments available to facilitate collaborative working. Of all these applications, groupware demands special consideration. 'Groupware' is the name given to application software developed to support the collaboration of several users (Dix *et al.* 1998). Some researchers treat 'groupware' as another name for CSCW. However, others argue that it is incorrect to use 'groupware' and 'CSCW' synonymously because of the technological focus relating to groupware and the range of social forms developed within the context of cooperative working.

These technological advances have resulted in new ways of working for all industries. Adopting these technologies, some industries have radically changed their ways of working. Organisations have developed new business models to exploit the opportunities offered by the technologies. The construction industry has not however 're-engineered' its business processes to the same extent as many industries.

The range of hardware and software available for use on a typical construction project has been summarised and mapped in the process protocol (Kaqioglou *et al.* 1998). This map of the construction project process represents a basis for evaluating and establishing the process and the roles of the participants.

Effective collaborative working in service-based operations needs to bring together the four key resources of people, process, technology and data (Chapter 13). Within this book we cover all these aspects. These four resources are reviewed from the perspectives of both collaborative design and collaborative construction in a new era facilitated by the emergence of BIM and related technologies.

Revolution

Design for the built environment is seen as one of the most multidisciplinary practices in all of the design professions, since many professions, including architects, civil engineers, building services engineers, quantity surveyors, construction managers and landscape architects, are required to work closely during the design phase. Collaboration among different participants in the design of a building involves both synchronous and asynchronous communication. The different participants require the ability to work on their part of the project using their own particular ways of working yet being able to communicate with the other participants to bring about a common objective, the design of the building.

Three major and interrelated approaches towards collaborative working may be identified: technology and methods, business environment, and human behaviour. In this book, we have provided a number of showcases from each of the three approaches to demonstrate their applicability and success in addressing the unique problems existing in the construction industry.

Computer-aided systems have been used for the creation of site drawing and layouts for a long time (Tavakoli and Klika 1991). With the increase in computer-aided design (CAD) usage, there has been an increase in the interest in collaboration using the electronic medium. However, the use of CAD systems was primarily restricted to communication of shape information in the 1990s, much of it in the form of conventional drawings created on wire-frame-modelling-based systems (Veeramani *et al.* 1998). Such models are unable to meet the requirements of collaboration. With the emergence of new technologies such as the Internet and networking, things began to change.

A major UK research project, '3D to nD Modelling', funded by the Engineering and Physical Science Research Council (EPSRC) developed multidimensional computer models to portray and visually project the entire design and construction process, enabling users to 'see' and simulate the whole life of the project (Lee *et al.* 2003). An nD model incorporates multi-aspects of design information required at each stage of the lifecycle of a facility, and provides a powerful mechanism to visualise the design, construction and operation process, and to integrate many other aspects of the process (Brandon *et al.* 2005). Marshall-Ponting and Aouad (2005) conclude that nD modelling could provide great value as a communication tool for industry and education.

In the aeronautical and automobile industries the use of BIM and VP is now commonplace, and all aspects of a new product or product changes are modelled virtually to assess the new product design, production and performance. This has revolutionised all aspects of design and delivery. We are currently experiencing a similar revolution in the design and construction of buildings. The last decade has seen the emergence of BIM and related technologies to a point where they may now be considered as the recognised platform for the design and construction of many construction projects. Their adoption has reached the 'tipping point' whereby their use may be expected to grow significantly over the next decade.

Eastman *et al.* (2008) define BIM as 'a modelling technology and associated set of procedures to produce, communicate and analyse building models' and characterise building models as intelligent digital representations of building components, which include data that describe how these behave. These data are consistent and non-redundant and may be combined in such a way that the model may be represented in a coordinated way.

Brandon and Kocaturk (2008) explore how BIM and the related technologies will present a new virtual future for design, construction and procurement. These technologies may be considered as a revolution for collaborative working because they will change *how* participants collaborate, *when* the project participants collaborate and the *contractual basis* under which they participate. The opportunities offered business organisations by these new technologies will result in the need for all businesses to review and refocus on how they add value to design and construction within this new business environment. They will also change the nature and timing of how design proceeds and how and when client value is added within the design and construction process. BIM and the related technologies will fundamentally change the project value chain.

BIM and related technologies will inevitably improve productivity and reduce waste within the construction process, change the role of professionals within the process and when and how they contribute their knowledge and expertise, enable data on individual projects to be shared within other larger models of the built environment, re-engineer existing business processes, and require new types of software and new technologies. Their introduction will succeed, however, only if the 'soft' aspects of systems and their implementation into organisations are considered, understood and taken into account.

Within this book the contributors review all these aspects.

Martin Riese (Chapter 8), in his review of the use of BIM on Swire Properties Hong Kong One Island East Tower project, describes how the adoption of BIM and related technologies throughout the design and construction process has helped to achieve a saving of at least 10 per cent in the cost of construction. He reviews the implementation of various key aspects of the building lifecycle information management techniques and the working methods that delivered success on the project.

The adoption of BIM will change the way that architects work. Kiviniemi and Fischer (Chapter 2) highlight that AEC practices are facing radical change because of the emergence of BIM. This change is affecting the architectural profession faster than other disciplines. They identify different dimensions of this problem and provide a practical approach to overcoming problems that emerge. Tuba Kocaturk (Chapter 14) identifies recent changes in architectural design culture due to extensive use of digital technologies and computational design environments, describes current digital design practice, and observes the ways and extent to which designers incorporate new tools and technologies into their working processes. She notes that

> One of the most crucial characteristics of this new field of design knowledge is that it is constructed collaboratively by the various parties taking part in the design and implementation processes. The emerging interactions between the design and production processes become highly non-linear and dynamic, leading to the emergence of a new, cross-disciplinary and collective body of design knowledge.

The importance of acquiring and utilising this design knowledge is emphasised by Rivka Oxman (Chapter 6), who looks at supporting multi-disciplinary collaboration through the integration of knowledge and information. She argues that 'computational enhancement of human collaboration . . . demands a shift from information-based technologies to knowledge-based technologies' and that it is necessary to replace 'the concept of the "building information model" (BIM) with the concept of the "building knowledge model" (BKM) [which] may support such a shift in supporting human collaboration in digital design'.

Kenny T. C. Tse, Andy K. D. Wong and Francis K. W. Wong (Chapter 12) also use the One Island East project as a case study to examine the role of BIM and its impact on the professions, confirming that, whilst the role of professionals in a BIM environment will change, the importance of their domain knowledge will not.

In Chapter 5, Souheil Soubra 'explores the possibilities of using geospatial information as input data to construct 3D models of the built environment.

The 3D models are then combined with simulations in order to address sustainable urban development issues within the planning process.' He also reviews the social, organisational and human issues that need to be considered when working in an interdisciplinary manner.

Godfried Augenbroe (Chapter 11) looks at applying process rigour to the use of BIM in building design teams and reviews three technologies. He reminds us that

> Building design requires an orchestrated team effort in which many actors, tasks and activities have to be coordinated. As different actors use different software tools, each specialist traditionally operates on an island of isolation until the time comes to match and patch with other members of the design team.

This requires the ability to execute and manage a wide range of software applications. This challenge of seamless data interchange is probably the major barrier to the widespread adoption of building information modelling. Interoperability, the ability to seamlessly transfer data between applications software, is essential for success.

Achieving interoperability has been the challenge for many researchers and industry experts for a considerable time. The IFC ('Industry Foundation Classes' or, more descriptively, 'Information for Construction') schema defines a standardised file format that can be used as a mechanism for sharing semantically rich building information between CAD systems and an ever-expanding range of design analysis tools (Plume and Mitchell 2007). Fisher and Kam (2002) used IFC technology to facilitate data exchange among the major design partners in the project. They concluded that, compared to a conventional approach, these relatively seamless data exchange and technology tools substantially expedited design and improved the quality of interdisciplinary collaboration. Since IFC files are textural files whose size can reach 100 megabytes, Renaud *et al.* (2003) introduce an approach that can automatically identify business objects in IFC files and simplify their visualisation and manipulation on the Internet.

Robin Drogemuller discusses issues relating to the sharing of information between different disciplines in collaborative projects. The focus of his chapter (Chapter 3) is the information dependencies and the representation of the information required for collaborative working and how these issues may be addressed.

Jeffrey Wix (Chapter 10) considers that, as BIM applications become used more extensively and as object-based information exchange occurs, the capabilities and limitations of current developments are becoming more evident and new techniques are emerging that offer significantly greater potential to change the ways in which the building construction industry works. He argues for an approach based on an 'information delivery manual' (IDM), and describes a manual that has emerged as a response to the needs of software users in applying and trusting the IFC model for information exchange and also provides support to software developers.

As BIM develops, the technology and software to drive and support the process will change. Peter Brandon (Chapter 1) examines the impact of new technologies: access grids, tele-immersion, collaborative virtual environments and immersive collaborative environments. Ghassan Aouad, Song Wu and Angela Lee (Chapter 17) explore the opportunities to apply gaming technology into the construction arena. The computer game industry has invested heavily in the development of sophisticated game characters and achieved impressive advances in both technology and its user base. Such an approach for construction may be expected to deliver more complex, psychologically valid simulation models. E. A. Obonyo and C. J. Anumba (Chapter 7) also focus on information exchange and interoperability. It is their contention that, although significant strides have been made in refining the capabilities of such applications, there is still no overall integration scheme for the sharing of information between the existing tools. They propose the use of an agent-enhanced knowledge framework within virtual construction applications not only to address information integration issues but also to make the modelling more intuitive and hence powerful.

BIM and virtual reality (VR) produce the ability to model and visualise both the design and the construction process, thereby facilitating collaboration between all parties within the design and construction process. The term 'VR' is similar to and sometimes used synonymously with 'visual simulation', 'digital mock-up', 'virtual prototyping', 'walk-/flythrough' and '4D CAD' (Whyte *et al.* 1999). There are many VR applications in architectural design (Campbell 2000; Kolarevic *et al.* 2000; Caneparo 2001) and construction planning (Retik and Shapira 1999; Waly and Thabet 2003).

Rosenman *et al.* (2007) present a virtual environment framework for multidisciplinary collaborative design based on a virtual world platform and a model for representing the same design from the perspectives of different disciplines. It is proposed that the views of the various disciplines are modelled in separate hierarchies and the relationships between the various models are specified. Collaboration takes place in a virtual world environment because the multi-user and immersive properties of such environments facilitate synchronous communication and simultaneous modification to the different discipline designs. One of the main advantages of a virtual world environment is that it allows users to be immersed in the environment, allowing for real-time walkthroughs and collaboration (Conti *et al.* 2003; Savioja *et al.* 2003).

Heng Li, H. L. Guo, T. Huang, Y. K. Chan and M. Skitmore (Chapter 9) emphasise the need for change and the adoption of VR. They remind us of the low levels of efficiency consistently achieved in the construction industry and argue that to achieve greater productivity we need an 'IKEA approach' to management – designers working with manufacturers to find smart ways of production. This demands 'design without errors and appropriate construction sequencing'. This, they argue, can be achieved through the use of virtual prototyping (VP) to integrate design and production.

The process changes required to maximise the benefits of BIM and collaborative working are considered by Matthew Bacon (Chapter 13), who stresses that for service-based operations (such as construction) effective collaborative working will not be achieved through people working slavishly in their own professional disciplines, which will only serve to impede the process, but through the adoption of new roles that recognise the needs of new working practices. 'When people work together systematically using integrated processes, sharing common data, seamlessly exchanged between heterogeneous systems, an efficient and effective service is likely to be the outcome.' He then describes how this may be achieved. Andrew Baldwin, Simon Austin and Paul Waskett (Chapter 4) emphasise the benefits that can be accrued from modelling and managing the information flow within the design process and its importance in effecting collaborative working.

Experience shows that if we do not pay sufficient attention to the 'soft' aspects of systems implementation then new systems invariably fail. Mohan Kumaraswamy (Chapter 16) argues that rapid developments in hard system collaboration tools have overtaken the current capacities of most construction organisations and personnel to effectively mobilise, let alone rapidly optimise, such multi-dimensional management systems. He highlights international and local initiatives towards redressing the present imbalance between hard and soft systems, and addressing the growing gap in their future development.

Peter Brandon reminds us that the focus of the industry in the last decade has been the processes of design and construction and a more efficient and effective design and construction procurement whereby the number of interfaces have been reduced by technology to reduce the enormous overhead of communication. He focuses on the role of management in collaboration and catalysts for change and concludes that we are already seeing clients demanding that their professional teams use 3D models and that these in turn are expanding to provide a total knowledge structure for knowledge development. Improved collaborative environments may be achieved by minimising the interfaces through automation and improved collaborative working.

The overriding factor that will ensure the successful adoption of BIM within design and construction is increased client value. Eastman *et al.* (2008) argue that 'cost estimation integrated with a BIM design tool allows designers to carry out value engineering while they are designing, considering alternatives as they design, that make the best use of the client's resources.' Incremental value engineering while the project is being developed allows practical assessment throughout the design. 'BIM may therefore be expected to revolutionise Value Management and the collaborative working of parties to ensure that the construction client achieves maximum value from the new building' (Eastman *et al.* 2008). The contributors therefore also focus on this aspect of collaborative working.

Geoffrey Qiping Shen, Shichao Fan and John Kelly (Chapter 18) focus on communication in decision making within the field of value management (VM), which is one of the most widely used tools to harness the creative powers of a group of people to achieve more than the sum total of each contribution. By definition, VM is a function-oriented, systematic team approach to provide value in a product, system or service in which the decision is made corporately through collaborative working (SAVE International 1998). The process uses structured, team-oriented exercises that make explicit and appraise existing or generated solutions to a problem, by reference to the value requirement of the client (Male *et al.* 1998). As a result of technological development, uncertain economic conditions, social pressures and fierce competition, construction industry clients are placing increasing demands upon the industry in terms of the project quality, costs of delivery, time from inception to occupation and, above all, value for money of projects. VM, as a useful tool that can help the industry meet these challenges, has been widely used in many developed countries for several decades. The implementation of VM in a construction project is normally in the form of one or more workshops, which are attended by the major stakeholders, facilitated by a value specialist, and follow a 'systematic job plan'.

In Chapter 18 Geoffrey Qiping Shen, Shichao Fan and John Kelly introduce 'a group support system for collaborative working in a value management workshop environment' to aid the decision-making process. A group support system (GSS) is an interactive computer-based information system which combines the capabilities of communication technologies, database technologies, computer technologies and decision technologies to support the identification, analysis, formulation, evaluation and solution of semi-structured or unstructured problems by a group in a user-friendly computing environment. As there is a strong demand for improvements to the practice of VM, research has been conducted to design a GSS prototype system, named Interactive Value Management System (IVMS), to explore its potential application in VM workshops and to investigate the effect of the application. Chapter 18 begins with an introduction to the problems of implementing VM in the Hong Kong construction industry. It then provides an illustration of the features of the proposed group support system, which has been developed in the research. Two validation studies designed to test the support of the proposed system are described, and the results are discussed. Findings from this research indicate that IVMS is supportive in overcoming the problems and difficulties in VM workshops.

Steven Male extends the discussion on the use of new technologies for value management in Chapter 15, where he reviews the use of 3D computer visualisation methods in value management briefing and design studies. He presents case study vignettes of how the requirement for such methods has arisen and possible solutions, recognising that the use of such solutions is likely to be the domain of large-volume procuring clients, the large contractors and consultants.

Summary

Building information management and virtual prototyping enable new ways of working. They harness the power of technology to aid communication and thereby encourage collaboration. The book explores how various technologies, methods and approaches provide the catalyst for change and begin to change the nature and form of the design and construction process. The new technologies will change the roles of the participants, and it will be some time before this can be assessed, as it is an evolving process. As this form of collaborative working develops, other considerations will need to be considered, including the 'democratisation' of design, changes in the power of the community, and collaborative working in its widest sense whereby all the stakeholders are actively engaged in the design.

Whilst the benefits of BIM and related technologies are increasingly apparent, so too are the barriers to its adoption. These challenges include, but are not limited to, challenges with collaboration and teaming, changes in practice and use of information, implementation issues, and legal changes to documentation ownership and production (Eastman *et al.* 2008).

Despite the recent development, the construction industry remains fragmented; this is further complicated by the applications of isolated technical solutions and the lack of interoperability of design tools. The drive for improved collaboration includes the effectiveness of organisational operation, the need for more efficient use of resources, and the desire to accomplish more than through reductionist approaches where islands of sub-optimisation are developed. The aim is to make the whole greater than the sum of the parts.

There are enormous challenges ahead which will require collaboration between the participants to the construction project coupled with an efficient, effective information exchange developed through technology and improved processes. This book represents the views both of researchers and of academics working in the field. It is early days, but these insights will provide an indication of the direction the industry should follow. It is important that the discussion continues if the construction industry is to emerge as an efficient and effective force for the development of human activity and accommodation.

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1 Collaboration

A technology or human interface problem?

Peter Brandon

The research agenda for construction has been dominated in recent years by the perceived need for a change in the *processes* of design and construction. In the UK, the Latham and Egan reports (Latham 1994; Egan 1998) have emphasized various aspects of this to enable a more efficient and effective design and construction procurement. The assumption has been that the process of construction design and assembly is where the focus should be, as this is where maximum benefit has been achieved in other industries. Part of this process issue has been the management of how the various parties to the process collaborate. If that collaboration breaks down then inefficiencies and abortive work emerge.

However, one of the major problems has been that traditional collaboration is operated through conventional models of procurement with a skilled but largely computer-naive workforce who are either unable or unwilling to adopt the new technologies to gain major long-term advantage. It is argued that the cost of change is just too high for an industry that works on low cost margins and would require a major restructuring of its workforce and a re-education programme for many of its employees. There have been no widespread role models which clearly demonstrate that any other alternative is superior and that commercial advantage can be achieved.

There is, perhaps, one major exception to the above and that is in the adoption of so-called *free form* architectures, because these structures cannot be built without the aid of 3D or nD models supported by a significant database of knowledge. In addition, the manufacture and assembly processes require a high level of technical support and tight tolerances which demand new forms of manufacture and CAD/CAM arrangements for major aspects of the construction superstructure. This necessity to harness the power of computers and their associated tooling mechanisms for manufacture provides a proving ground for the changes that might be expected for the wider industry.

At the moment this technological change is perceived to be costly, and there is concern that there are insufficient skilled workers to be able to use the technology effectively. The design team of most major projects is still operating only at the periphery of the technological revolution which could change the construction industry across the board. There is a strong need to reconsider the whole of the procurement process and, in particular, the processes of construction to establish what changes would be required to provide the most effective approach to collaborative design and manufacture to harness the new technological infrastructure which is emerging.

The changes required include education, the structure of the industry, the need for collaborative working across geographical boundaries, the models which support the new processes, the methods of communication, and the limits to innovation for construction. Free form architecture is currently the test bed for these activities, because the motivation is there, with a group of designers and technologists who are at the leading edge of both their own industry and that of the adoption of information and communication technologies (ICTs). There is a strong need to benchmark their progress against conventional approaches to demonstrate overall benefit but also to determine where the priorities for the revolutionary approach should lie.

This is not a trivial issue, and the following discussion seeks to highlight some of the matters that need to be considered, particularly with regard to the management of design and construction.

The role of management in collaboration

Process by its very nature is bound to consider the management of that process and where responsibility for activity lies. Management is an intervention which attempts to try to improve the efficiency and effectiveness of the activities which have to be undertaken to achieve a given end. Inevitably, this must include the manner in which all the various participants collaborate to reach the desired objective. Dictionary definitions of management are quite broad but include:

- 'to direct or control the use of';
- 'to exert control of';
- 'to direct or administer the affairs of';
- 'to contrive or arrange, succeed or accomplish, especially with difficulty'.

Much of the perceived difficulty lies in the way in which people collaborate and, increasingly, the way in which people use and interface with the technology.

However, there is a paradox in that as management is introduced to cope with complexity very often the more we manage the more complex the process becomes! Perhaps one of our targets should be to minimise the amount of management required in any given project without jeopardising the ability to be efficient and effective. Management is an overhead, and one of our targets should be to reduce it.

Of course, it is not possible to do entirely without management in some form. All we can do is question where it resides, who does what and how much it can be automated. The latter question suggests that it may be possible to reduce the human input at least, and this may well result in further efficiency. This is a role the technology can play, and innovative methods are now being developed.

The position of project management is already under debate from those who have had to challenge the traditional processes in order to get their buildings built. Often these are the designers who are responsible for some of the most exciting designs which are seen in our major cities. One of the pioneers in automating the process is Jim Glymph, previously senior partner of Frank Gehry Associates. His experience with dealing with the management of large-scale complex projects has led him to believe that in some instances project managers can get in the way.

In commenting on the Gehry fish sculpture for the Barcelona Olympics (Figure 1.1) he said that his firm agreed to go ahead with the project, which had a particularly tight schedule, if project managers were left out and there was agreement with the city of Barcelona that they could operate outside some of the conventions required by the authorities. These conventions

Figure 1.1 Barcelona fish sculpture (Frank O. Gehry & Associates Inc. (Gehry Partners, LLP), 1992).

and regulations were introduced to improve matters, but then the technology overtook them (e.g. the requirement for 2D drawings for regulation purposes when 3D is essential to understand a free form building) and they became impediments.

As Jim Glymph states with reference to the fish sculpture:

> In construction, you know, there's been a tradition, built up about paper and process, an approval process that is very complicated. We didn't sacrifice any quality control procedures; we clearly did not sacrifice any management; we just eliminated management where it was not necessary, which was most places.
>
> The fish sculpture was a fairly easy, steel structure, metal skin; it's not like the other buildings we are doing now . . . but the big road block is still management.

Now this is a fine statement to make, but it is not quite as simple as it sounds. Because there was an element of automation introduced into the process then management was reduced, but what he is really arguing is for the designers to undertake the management in-house without a third party being involved and that the collaboration required to undertake the project is kept largely within the control of one organisation, thus avoiding the problems of collaboration between firms. This is a shift back to the processes adopted more than two centuries ago. Then the designer/engineer was responsible for all activity and management. With the rise of the general contractor and increasing complexity of buildings, more specialisms were introduced, resulting in more interfaces and knowledge silos, engaging many more professional advisers all trying to protect their own interests. In the end the designers (or their clients) outsourced nearly everything except form, specification, mass and space articulation on major projects (see Figure 1.2).

In more recent years, and particularly the last decade, the fragmentation has been identified as a major problem, and the introduction of new technologies which aid collaborative working, such as the internet, has suggested that we could move back to a united design/construction team aided and supported by technology, but it will mean a different set of procedures and protocols.

Addressing the problem

At the heart of the management function is dealing with the interfaces between people, organisations, physical artefacts, supply chains, technology and whatever else involves two or more people or artefacts creating some level of interdependence.

Figure 1.3 shows, conceptually, such a possible interface. It might be between two people or between people and technology or between a person

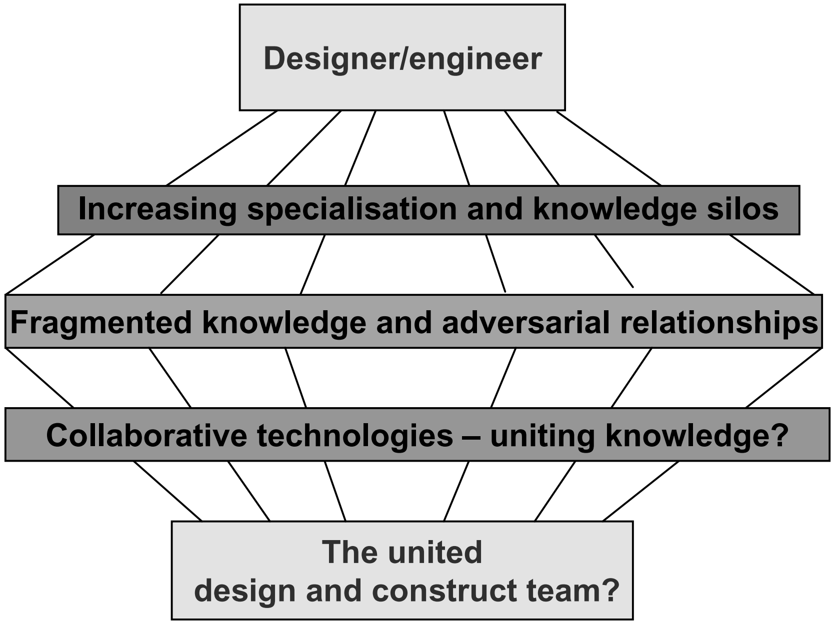

Figure 1.2 The expansion and contraction of collaborative relationships?

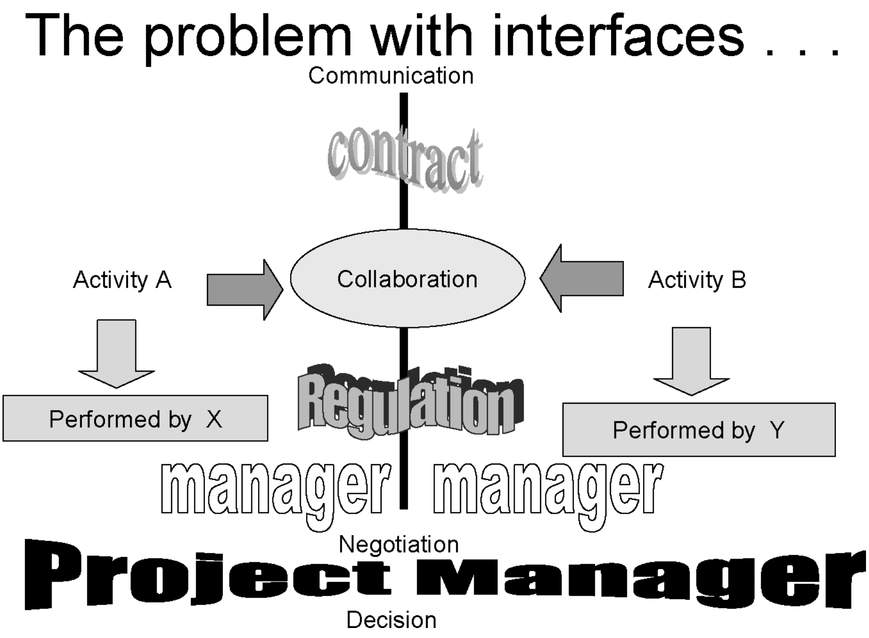

Figure 1.3 The issues surrounding collaborative interfaces.

and an organisation. It is worth noting the following possible build-up of the managerial function:

- Initially activity A needs to work with activity B.
- In order to do this both parties have to collaborate.
- The end result of the collaboration could involve a negotiation and/or a decision.
- The negotiation will involve some kind of communication, which is normally oral or written but could be electronic to a machine.
- At some point this process between the two may need to be clarified in a contract so that both parties understand the intentions of the other.
- The action and dependency might well be so significant that it is thought appropriate to develop regulatory powers to ensure that the public or the parties are protected in some way.
- The process is now becoming so complex that one party decides to appoint a specialist manager to handle the situation.
- The other party observes this and appoints a manager so that there is equal expertise available in the process.
- There comes a point when the managers can't agree and it needs someone to come in over the top and project-manage the managers! The project manager has arrived!

The above is, of course, a caricature of what happens, but nevertheless there is a ring of truth. In some circles this is called *creeping managerialism*, and it is something which pervades much of at least Western society, where the understanding of trust as an element of working practice has begun to break down.

The interface problem can be seen in a simplified cut-through of the procurement/estimating process. Figure 1.4 shows how information is transmitted through the system as the various parties attempt to collaborate.

In this case a set of professionals including the client are transmitting knowledge from one to the other to enable the building to be built. The process follows a familiar pattern:

- The client briefs the architect but can't articulate all his/her requirements – but does his/her best!
- The designer takes the brief and expands it from his/her own knowledge and experience and produces a design.
- The designer communicates the design through a model to the estimator, but the model is by definition a simplification of what he/she knows and is, therefore, not complete.
- The estimator interprets the model from his/her own experience and knowledge, expands some of the knowledge to suit the estimating process and prepares a bill of quantities.

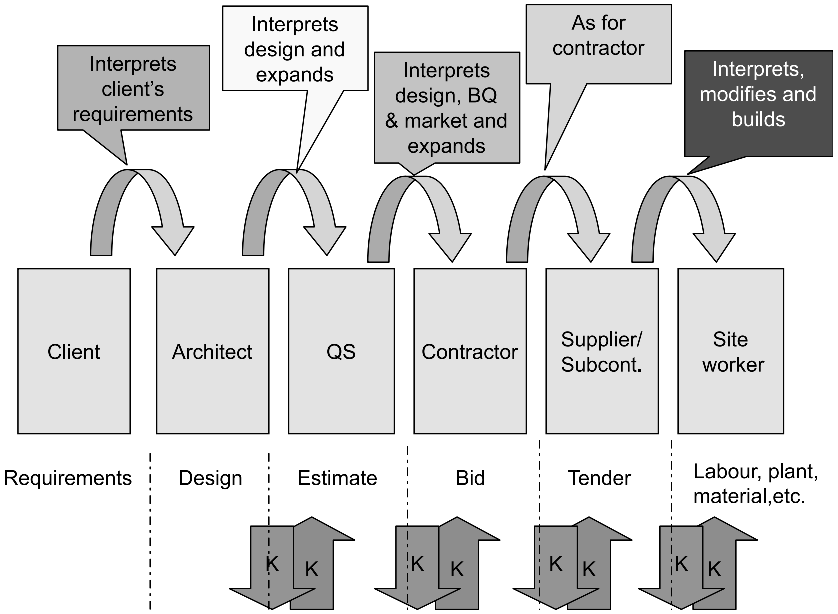

Figure 1.4 Professional interfaces and knowledge entropy.

- The bill of quantities is a simplified model of what is required to estimate cost, and therefore the bidders have to use their knowledge to expand the content and judge the cost of works.
- When they gain the job through competitive tender they then have to communicate to the site workers what has been assumed, and this again takes a different form and will be incomplete.
- The site worker takes the information and uses his/her expertise to actually make the information work in practice!

Throughout this process of collaboration, knowledge is being lost and gained. At each interface there may be a contract or some regulation that must be complied with and very often a negotiation/decision to be made based on incomplete information. The models used by the participants may not match each other. All these issues at the interface provide the potential for a breakdown, which can result in inefficiency and ineffectiveness. It is not clear that any amount of external management will solve the problem. At root is the interface itself, together with the models which each individual or organisation is using.

The result is:

- a failure in manual systems through potentially adversarial relationships;