ICCI Best Practice Guide

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Summary

This deliverable is the second and final version of D31 “ICCI Best practice guide”, which results from the work in Task T31 of WP3. This task is concerned with identifying the current limitations in the Construction sector in terms of human and organisational resource management, and investigating the human and organisational aspects in relation with the use and deployment of ICT in Construction in order to formulate critical success factors for the future of the sector.

The document is introduced with a description of the ICCI work package and the companion deliverable produced from Task T32. The term ‘best practice’ is then defined, and the limitations imposed by the fact that the majority of the ICCI member projects have not addressed human and organisational issues are explained. The construction industry is described in terms of its structure and unique characteristics, in order to place the research and the document in context. This is followed by a description of the current ‘average’ practice and best practice concerning ICT in use in the construction industry. The main focus of the document is human and organisational issues with respect to the use of ICT. After describing the human factors and issues that are emerging as the most important, the document then proposes a best practice business strategy. This section introduces themes to address in development of a strategy, indicates critical success factors, and proposes a pragmatic migration strategy model for use by managers and other practitioners in the sector.

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<tr>
<td>CAD</td>
<td>Computer Aided Design</td>
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<tr>
<td>CBR</td>
<td>Case based reasoning</td>
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<td>CORBA</td>
<td>Common Object Request Broker Architecture</td>
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<td>CSCW</td>
<td>Computer Support for Cooperative Work</td>
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<td>eConstruct</td>
<td>Electronic Business in the Building and Construction Industry: Preparing for the new Internet</td>
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<td>eLEGAL</td>
<td>Specifying Legal Terms of Contract in ICT Environment</td>
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<td>EDMS</td>
<td>Electronic Document Management System</td>
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<td>FM</td>
<td>Facilities Management</td>
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<td>GLOBEMEN</td>
<td>Global Engineering and Manufacturing in Enterprise Networks</td>
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<td>GPRS</td>
<td>General packet radio service</td>
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<td>GSM</td>
<td>Global system for mobile communications</td>
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<td>HCI</td>
<td>Human Computer Interaction</td>
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<td>ICCI</td>
<td>Innovation co-ordination, transfer and deployment through networked Co-operation in the Construction Industry</td>
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<tr>
<td>ICT</td>
<td>Information and communication technology(ies)</td>
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<td>IFC</td>
<td>Industry Foundation Classes (collective description for the IAI project data model framework)</td>
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<td>IST</td>
<td>Information Society Technologies</td>
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<td>ISTforCE</td>
<td>Intelligent Services and Tools for Concurrent Engineering</td>
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<td>IT</td>
<td>Information Technology</td>
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<tr>
<td>KBS</td>
<td>Knowledge based system</td>
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<td>OLAP</td>
<td>On-line analytical processing</td>
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<tr>
<td>OSMOS</td>
<td>Open system for inter-enterprise information management in dynamic virtual environments</td>
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<tr>
<td>PDA</td>
<td>Personal digital assistant</td>
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<tr>
<td>RTD</td>
<td>Research and Technology Development</td>
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<td>SME</td>
<td>Small / medium size enterprise(s)</td>
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<td>STEP</td>
<td>STandard for the Exchange of Product Data (ISO 10303)</td>
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<td>UML</td>
<td>Unified modelling language</td>
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<td>VE</td>
<td>Virtual Enterprise</td>
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<td>WP</td>
<td>ICCI Work Package</td>
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1. Introduction

The general aim of the ICCI cluster is to improve harmonisation and coherency of research and development, and thereby to benefit efficiency in IST projects, assist knowledge transfer to industry, and reduce time to market of exploitation. ICCI acknowledges that deploying and using IT in construction is nowadays less a matter of cutting edge technology, than a combination of technology, organisation, marketing, legal frameworks and social impacts. Therefore, it is the intention of ICCI to start paving the way to such combination for the construction sector.

From the above context, WP3 is directly concerned with the organisational issues and social impacts – overall the human and organisational aspects for ICT in construction. In an attempt to enhance the competitiveness of the construction sector, the Commission of the European Communities produced a report (European Communities, 1997) identifying the key interrelated elements of competitiveness. Among other factors, the European Commission highlighted the importance of organisational and human issues. More specifically, the importance of human resources was recognised, noting the need for effective health and safety measures as well as training and professional development in order to develop a stable and well-educated workforce. This work package aims at integrating human, organisational and technical elements throughout the project in order to enhance the capabilities of the construction sector.

The above general aim of WP3 translates into the measurable objectives:

• To address and examine human and organisational issues related to the development of the construction sector and formulate critical success factors for the future of the sector.

• To collect best practice from member projects and prepare a consolidated guide in order to enable construction companies to formulate a business strategy incorporating new technological capabilities, to re-engineer the processes to support new functionalities and improve performance and to manage successfully the organisational change.

• To collect and synthesise results and information regarding training needs of construction employees.

In order to achieve these objectives the work package is divided between two principal tasks:

Task T31: Best practice guide. This task is concerned with identifying the current limitations in the Construction sector in terms of human and organisational resource management. It will also investigate the human and organisational aspects in relation with the use and deployment of ICT in Construction in order to formulate critical success factors for the future of the sector. The current report is the second iteration (final) output for this task, and is aimed primarily at industry managers and practitioners, but also to the research and academic communities.
Task T32: Specifying the training needs of employees in the construction sector. This task has been achieved by establishing an initial indication of training needs through synthesis of results from the ICCI consortium, followed by critical analysis by a forum of experts in human resource management and professional development. These activities enabled the specification of the needs for training and a strategy was developed to address those needs. The output of this task is ICCI deliverable D32: *ICCI Action Plan on training in construction* (Rezgui et al., 2003).

### 1.1 Scope and limitations

This document deals with best practice and in order to understand the aim fully we need to ask the question ‘What is best practice?’

The following definitions of best practice from the literature, were found to fit best with the understood meaning in the context of this document:

- “The identification of policies, procedures, and programs, referred to as the critical success factors, that top performers are using that lead to superior performance.” The selection criteria for Best Practices: “Best Practices may be identified as those activities that are new, innovative practices that are successfully incorporated into an organization/industry for the first time. Other identifiers - practices that are systematic, eliminate waste, maximize resources, etc.” – Centre for Advanced Purchasing Studies (CAPS) http://www.capsresearch.org/research.htm

- “To us, ‘best practices’ are documented strategies and tactics employed by highly admired companies. These companies are not ‘best-in-class’ in every area - such a company does not exist. But due to the nature of competition and their drive for excellence, the profiled practices have been implemented and honed to help place their practitioners as the most admired, the most profitable, and the keenest competitors in business.” – http://www.best-in-class.com

Best practice can therefore be summed up as the adoption and development of ideas, systems, or methods in a way that measurably improves a business or enterprise so that it continually offers or secures the best value for money. In many cases the knowledge required to improve the business can often be acquired by learning from other companies, who have already faced and addressed similar concerns. It should be noted that ‘Best Practice’ is not prescriptive, for the simple reason that companies within the construction sector differ quite widely, thus the solutions that may work for one company may not work for another.

The initial work towards realising the best practice guide concentrated on gathering information from the ICCI member projects’ deliverables and discussing with the project partners the extent to which human and organisational issues have been addressed. It soon became apparent that the majority of human and organisational issues within the aims of WP3 had not been addressed in the member projects, with the exception of OSMOS.
Due to this limitation the information recorded herein is the result also of extensive research from external reports, papers, white papers, web sites, etc.

1.2 Structure of the report

The report is divided into the following six chapters:

Chapter 2: presents firstly the characteristics of the construction industry, which serves to place the research in context.

Chapter 3: aims to describe the current usage and common practice of ICT in the construction sector. It draws on available literature and also on results from the ICCI member projects, including surveys carried out within the OSMOS project.

Chapter 4: describes a selection of the latest ICT developments that are currently in use in the construction domain, with a focus on the benefits that can be gained from improved information and knowledge management in the enhancement, development and improvement of professional expertise.

Chapter 5: following the presentation of the technologies in use in the sector in the previous chapters, this chapter presents results from the available research in human and organisational issues in construction. These results are based on EU reports, facts from the literature and other reports and results from the participating projects.

Chapter 6: presents the emergent themes that should be addressed in development of best practice business strategy, and the critical success factors to be taken into account. The final section presents a proposed migration path to best practice, introducing the ICCI Best practice business strategy migration model, which can be used to identify opportunities for action and provide support for taking action through a series of phases.

Chapter 7: concludes the document and proposes future recommendations in terms of extending the research in this discipline within the construction sector.
2. Background

2.1 Overview

The development of this ICCI guide to best practice with regard to ICT in the construction sector was dependent on available materials from the ICCI member projects, together with information from external sources including reports, papers, white papers, web links, etc. In addressing the human and organisational issues it is also necessary to be aware of the ‘bigger picture’ in terms of the construction sector as a whole.

This chapter presents the characteristics of the construction industry, placing the research in context, and an overview of the objectives of the ICCI member projects.

2.2 Structure and characteristics of the construction sector

It is commonly accepted that the construction industry exhibits characteristics that differentiate it from other industrial sectors, with some of these characteristics being unique to construction. The following is synthesised from various sources (European Communities, 1997), (Manseau, A., and Seaden, G., 2001), (Wilson, I.E., et al, 2001):

- The sector is heterogeneous and highly fragmented, depending on a large number of very different professions and firms, which are mostly small in size, tend to respond to local market needs and control only one element of the overall building process.
- Construction is one of the most geographically dispersed sectors with marked regional differences.
- Construction is highly project oriented, which influences the incentives, accounting, etc., and any ICT used within a project must be deployable and profitable within one project to all/several partners.
- Each construction project, whether to create a new facility, or a renovation/repair project is a prototype. The final product tends to be very durable, lasting 25-50 years and longer, and represents one of the few non-transportable industrial products. When construction facilities become obsolete they are most often repaired, modernised and sometimes radically transformed to suit new requirements rather than disposed of and replaced with new, which is more typical for manufactured products.
- The sector is highly regulated. Regulations and standards are more rigorous in construction than in most other sectors of economy, with the involvement of several levels of governments (local, provincial, national).
- The entry-level for new contractors is relatively low because the need for operational capital is small.
- The sector is very labour intensive, with high mobility of the workforce and growing skills needs as construction technology becomes more sophisticated. The duration of contracts is often linked to the length of the site construction phase.
• Business relationships are temporary and often short-term, bringing together partners who may never work together again.

There is a *de facto* recognition that the construction industry has for decades adopted the modus operandi of the ‘Virtual Enterprise’ (VE), which many of the above characteristics verify. In terms of the research efforts with respect to ICT in the construction industry, the list of characteristics of the construction industry can be extended:

• Within a project VE there is often no dominant actor to enforce ICT solutions.
• Information exchange within any construction project is mainly between others than the client and is not, therefore, contractually controlled.
• All actors are involved in numerous VEs at the same time.

These characteristics play a large part in shaping the research efforts for the industry, as they also implicitly point to problematic issues. Equally, they can be viewed as moderating factors in considering the results achieved. An example of this is that it should be borne in mind that the results from the OSMOS project, used extensively here, represent only a very small section of the industry at large.

Recognition should be made of the fact that construction is the largest industrial sector in the EC, with gross output representing approximately 11% of Community GDP and 5.6% of the value added. It is also the largest sector in terms of employment, providing jobs for some 7% of the working population, and it is a key sector for job creation with every job created in the construction sector generating two further jobs in related sectors (European Communities, 1997). It should be clear from the above that human and organisational issues in such a sector are no small matter and therefore deserve recognition in any research and development efforts.

The structure of the sector, however, being predominantly composed of small/ medium size enterprises (SME), means that many companies cannot be directly involved in such research initiatives. In the analysis of its Communication on Competitiveness, the EC highlighted quality, markets, construction process, regulatory framework, human resources, technology, and the structure of the sector as factors that determine the competitiveness of the sector. The member projects of ICCI can all be seen as responses to these factors. For example, a key theme is the ‘virtual’, or inter-enterprise nature of the solutions sought. With respect to the structure of the sector the EC found that a key factor in increasing the competitiveness of small businesses lies in the development of closer co-operation and the creation of associations between themselves, incorporating such ideas as “networking” and the establishment of “quasi-businesses” (European Communities, 1997). The ICCI member projects work towards improving amongst other things the sharing of information, ideas, and common services, support systems for the establishment of business partnerships, and a framework for legal conditions and contracts regarding the use of ICT in project business. It is recognised that innovation is a key factor in industrial competitiveness, and from a technological standpoint the Internet has become the international standard for electronic communications. The adoption and adaptation of technology is therefore a key to the future of the sector, but at the same time the fact that construction is such a labour intensive industry points clearly to the need for a focus on human issues. Its people bring the industry to life, not
merely its technology. A further pressing need within the sector is that of training. This specific aspect is dealt with in detail in the ICCI deliverable D32 *ICCI Action Plan on training in construction* (Rezgui et al., 2003).
3. Current ‘average’ practice

3.1 Overview

From reviewing the literature it is clear that there is a common acceptance that the construction industry is conservative and slow to take up new technologies. In reporting the image of the sector the EC (European Communities, 1997) stated that “the general picture of the European Construction Sector is one of a low technology sector, somewhat backward, which is desperately trying to change its image but finding it very difficult to do so.” The construction industry, in common with other industrial sectors is becoming highly information-intensive, however, and advances in personal computer technology, along with the rapid evolution of graphical user interfaces, networking and communications have had a substantial impact on industry business processes. The industry has, over the last decade, begun to embrace ICT to address the ever-growing pressure from clients to deliver high-quality facilities on time and on budget, resulting in IT-supported forms of project management and support for business processes (Rezgui, 2001).

To produce a report detailing the current usage and common practice of ICT in the sector, the ideal situation would have been to carry out a survey, especially amongst the partners of the ICCI member projects. Furthermore, with respect to human and organisational issues, it would have been important to ensure that such a survey were to question not only which technologies and methods are used, but also to gauge the opinions of the people who use them. Due to the time and budget constraints of the ICCI project, however, this was not possible, added to which industrial organisations are known to be presented with many such surveys, often resulting in poor data being gathered because of a reluctance by users to complete them. It is important to note here that the ICCI project recognised other clustering initiatives concurrently in progress and nurtured, for example, a symbiotic relationship with the IST-funded ROADCON project. This important initiative, which has formed a critical mass towards the future direction of the industry research efforts, undertook a comprehensive survey including human and organisational issues. Equally, in developing this survey ROADCON drew on expertise from ICCI member projects. This chapter aims to describe the current situation with respect to ICT use within the construction sector. It draws on available literature and also on results from surveys carried out within the OSMOS project (Wilson et al., 2002).

3.2 Access to and use of ICT

As stated above the structure of the construction sector predominantly consists of SME. In the UK alone, for example, from a total of 163,426 firms of private contractors in the year 2000, 87,712 or more than 50% comprised one individual (DETR, 2001). As such, figures are not available regarding the access to ICT throughout the industry, though some studies have been carried out that provide indicative results for specific areas within Europe. One such study is the so-called IT-Barometer (Howard et al., 1998; Samuelson, 2002), started in 1997 as an
initiative of the Swedish R&D-program, which aims to be a repeatable survey for measuring the use of IT in the construction industry that is comparable over time and between countries.

In the 2000 survey (Samuelson, 2002) reports that 88% of all employees in the industry work at workplaces with computers, which is approximately the same level as the previous survey (Howard, et al., 1998); most of those who do not, work at small companies with less than nine employees and with a large proportion of skilled workers. The survey points out that 54% of all employees in the industry have their own computer, and 33% have a computer at home that is owned by their company. The figures included both white-collar and skilled workers, with an indication that access to a computer for personal use among white-collar workers had increased to a high level in all categories of companies. The most common types of software used were revealed to be word processors, administration software, e-mail software and spreadsheets. It should be noted here that the Nordic countries are generally ahead of the rest of Europe in their use of IT. However, in the research into human and organisational issues in the OSMOS project, an IT and Construction questionnaire was completed by personnel in the three industrial end-user partners in France, Finland and Sweden, and semi-structured interviews were conducted with senior people such as managers, senior managers and company owners. The ‘most commonly used software’ results showed some similarity with those in the IT-Barometer survey. 86% of the questionnaire respondents indicated that they use (MS) Office applications in their work (with the Swedish partner indicating that it primarily uses computers for MS Office applications). An important finding from this survey was that a significant proportion (41%) of the respondents indicated that they needed further computer training. Figure 1 shows the most common training requirements by category.

![Figure 1: Computer training requirements](image-url)
MS Office software applications and project management tools were the areas in which the highest training needs were indicated, and although this is unsurprising regarding MS Office software, considering the high proportion of their use, only 42% said that they use computers for project management, so the requirements for further training in this area are notable.

The IT-Barometer 2000 survey shows the extent to which computers are used for different operations. Bookkeeping and invoicing are the common operations that are most frequently performed with computers, with over 60% of the industry using computers all the time for these operations. Tendering operations indicated c.40% computer usage and marketing c.12%.

Computer aided design (CAD) is now widely used throughout the construction sector, though drawing by hand has not been entirely replaced. According to (Samuelson, 2002) the most common software is AutoCAD, which is used 76% of the design time by engineers and 57% of the design time by architects. Architects use drawing by hand 23% of the time while the engineers only use this 11% of the time. On the other hand architects use model-based programs, such as ArchiCAD and AutoCAD ADT, to a greater extent than the engineers, who do not use them at all. Another difference between the categories is that 11% of the engineers use other types of software than those listed in the survey, while only 1% of the architects do this. The reason is probably that architects are a more homogeneous group than the engineers. Different types of engineers need different kind of applications.

These figures compared with the earlier survey showed that the total use of CAD in design work is increasing. The Swedish interviews in OSMOS indicated that all drawings are produced electronically. In the Finnish interviews the use of computers indicated that age is a moderating factor in the use of computer tools, a specific example being the use of CAD. It was noted that the various levels of use of technology could cause problems in team working. For example, older employees are used to making drawings on paper whereas younger employees use AutoCAD in order to produce their designs. As a result, it is difficult to create a co-operative climate among teams because of the frictions coming from different ways of working and different mentalities and approaches.

A lot of computer software has been developed for scheduling and resource planning processes. The IT-Barometer survey however shows that these operations are performed with computers by a surprisingly low share of the industry, with 14% of contractors performing all planning manually and only 10% using computers all the time. Architects and engineers were found to use them a little more, with 27% of engineers performing planning with computers all the time. The OSMOS research indicated that time planning, scheduling and the availability of human resources were constantly problematic. Short time scales and time management, simultaneous management of projects, and problems with scheduling were all stated as the most difficult aspects of people’s jobs in the questionnaire responses. From the interviews the majority of the interviewees indicated that an overall agreement to use electronic tools for these tasks would be welcome, though difficult to achieve.

The IT-Barometer survey also provided results for costing and budgeting operations, for which various software tools are available, from common spreadsheets, to specially developed costing software with databases for prices and products. Property managers were found to make the most use of computers for this purpose, whilst contractors have the lowest
use. However, it is remarkable that there are architects, engineers, and contractors, who perform this totally manually. For the contractors this figure is in fact 9%.

3.3 Communication

As the characteristics of the construction industry indicate, the modus operandi of the sector is that of the VE. Good communication, therefore, is of paramount importance as the level of information in the industry continues to increase, and construction projects become increasingly international in scope. Communication takes place at different levels: within teams (which may themselves be virtual), between teams and departments, and with external partners. Increasing use and reliance on technology for communications is somewhat problematic when considering the fact that most end-users in the construction industry are not computer-literate (Rezgui, 2001). The processes of design and construction are complex, and involve a substantial tacit knowledge, which complicates communication between different professionals (Bower et al., 2001). Most information used during the design-and-build process of a construction project is conveyed using documents, which are most of the time exchanged, for contractual and legal reasons, on a paper-based medium, even when produced using computers (Rezgui, 2001). (Though it is worth reiterating here the major goal of the eLEGAL project, being to define a framework for legal conditions and contracts regarding the use of ICT in project business, and the development of legal support tools for the use of ICT in construction, contractually stipulating inter-enterprise information exchange using ICT). However, the Internet is now widely used and web-based services are increasing in use.

According to the IT-Barometer 2000 survey (Samuelson, 2002) 83% of all employees in the industry work at workplaces with access to the Internet, where at least one person has access, and all workplaces with 50 employees or more have a connection to the Internet. The OSMOS surveys revealed that all three end-user companies have Internet access, though the French partner related some problems with the Internet due to the subsidiary companies all being independent, with each subsidiary having personal access to the Internet. From Internet technologies the intranet was spawned, together with the concept of project webs. The IT-Barometer survey found that only 25% of all employees work at workplaces where a project web has been used in any project, though among architects, engineers and property managers the figure is considerably higher, about 50%. The use of project webs was found to correlate with the size of companies however, with a figure of 75% for companies with 200 employees or more. The OSMOS survey showed that whereas the Swedish partner had a well-used intranet where the company’s employees are able to share news and information, the French partner did not. A network was in place for sharing printers, etc., but it was difficult for example to send a message to another person internally.

Company websites are also common, the IT-Barometer showing that in total 60% of the employees in the industry work at workplaces where the company has its own website, with the figure for manufacturer/trade being slightly higher at 70%, and among property managers it is considerable higher with 90%. The probable reason stated for this is that these categories have activities that are suited for offering products and services over the Internet. This statement is tempered however, when the report continues with respect to electronic trade,
stating that electronic trade is not widespread in the industry, with 64% of all employees working at workplaces that do not use electronic trade at all (Samuelson, 2002).

Within the OSMOS questionnaire, the respondents were asked to indicate the methods they use for communications within their teams. Figure 2 shows the five most important categories and how they compare in percentage terms.

![Figure 2: Communication methods within the team](image)

Clearly, almost everyone uses the telephone and a significant percentage use e-mail. It is interesting, however, to note that as many people rely on informal gatherings as they do on e-mail, and the use of groupware is significantly low.

As the majority of information in construction projects is document based, the extent of use of digital distribution of documents is still very low, due in part to legal and contractual issues. Many of these issues have been investigated and documented in deliverables in the eLEGAL project. Within OSMOS the end-users surveyed indicated some use of electronic document management systems (EDMS), with the French and Finnish partners using proprietary systems, and the Swedish partner also relying on its intranet, though people still tend to print documents and save the hard copies. The OSMOS questionnaire asked what problems the respondents experience with the information they share. The answers to this open question were again grouped into the following categories:

1. **Information** – factors including volume of information and information management.
2. **People** – factors including people’s involvement in processes, and skills.
3. **Technology** – factors including hardware and software.
In terms of the volume of information, it is interesting to note that whilst some people mention information overload, others note that there is too little information being shared. Information management problems are frequently cited as being problematic in this question. Versioning and storage of information are important, and are exacerbated by software problems such as incompatibility and formatting difficulties. Differing communications methods and use of computers are also perceived as problematic. The human issues here include differing levels of IT skills, and process problems such as people not checking their e-mails and other communications media, and misunderstandings due to delay. Once again the responses here point out the importance of people and process issues, but equally a correct architecture for the VE in technical terms is important for the still very real problems being experienced regarding information sharing and collaboration. Following this, the respondents were questioned regarding what they would change in their team’s communications practices, and how they think teamwork methods could be improved. The answers to these questions lean towards increasing the number of meetings, a wider use of e-mail, improved archiving and sharing of information, and once again, more training.

The IT-Barometer 2000 found that minutes of meetings were the document type most commonly sent digitally, though the level is low compared to the benefits offered by email in relation to ordinary mail in terms of economy and speed. The share of descriptions sent digitally was lower, and orders, invoices and tender enquiries were much lower. It was suggested that this might depend on security problems and/or lack of standards for digital signatures. The survey results regarding graphical documents were separated into the three stages of the design process: drafts/programs, construction drawings and as-built drawings. Construction drawings were the graphical documents most frequently sent digitally. Half of the architects and engineers were found to send 60-100% of their graphical documents digitally. Contractors, on the other hand, rarely send graphical documents by electronic means in all stages, and it was found that quality results and testing-results for materials were seldom sent digitally. Manufacturer and trade were found to do this most frequently, with slightly less than 20% sending this type of material more than 60% of the time (Samuelson, 2002).

3.4 Future perceptions from the OSMOS survey

The surveys carried out in the OSMOS project are quite unusual within IST projects, taking the clear stance that ICT are an enabler in business processes, and essentially it is the human using them who dictates their worth. An interesting result from OSMOS was found with respect to the future. The questionnaire survey asked the respondents to list the main factors they think are critical to the future growth and success of their company, and to rank them in order of importance. (It must be noted here however, that this question was only included in the questionnaires for completed in France and Sweden). Of the available respondents 68% gave answers to this question. It was found that these textual answers could be categorised into four main areas:

1. **Human Resources** – factors such as knowledge and training, and human resource management, including motivation and competence.
2. *Organisation / Process* – factors including teamwork, political decisions and customer relations.

3. *Production* – factors including costs, market knowledge and product development.

4. *Technology* – factors including new technologies and information management.

Up to four factors were indicated by the individuals who responded, with the majority (88%) giving at least two. Table 1 shows the breakdown of responses according to the four main categories above, from those that gave two (or more) critical success factors.

<table>
<thead>
<tr>
<th>Category</th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Resources</td>
<td>7</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>Organisation/Process</td>
<td>7</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>Production</td>
<td>7</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td>Technology</td>
<td>4</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>

*Table 1: Perceived critical success factors*

From this it can be seen that overall factors concerning production are perceived to be the most important, followed closely by the predominantly human factors covered by the human resources and organisation/process categories. Technology, however, is perceived to be of least importance in terms of these categories, with only four people suggesting any factors at all.

A further question, however, asked whether or not the respondents perform any work tasks that they feel could be improved by using computers. The respondents suggested a variety of tasks, which fall into four categories:

- Electronic communication – group address book, information diffusion
- Workflow – workflow, purchasing, statistics, planning management
- Document cross-referencing – handling drawings, management of plans
- Application inter-working services – intelligent design
- Scheduling services – calendar planning
4. Current best practice

This chapter describes a selection of the latest ICT developments that are currently in use in the construction domain, with a focus on the benefits that can be gained from improved information and knowledge management in the enhancement, development and improvement of professional expertise.

4.1 Overview

While the construction area is becoming an information-intensive industry, a new activity emerged the last two decades as current best practice from the process of managing projects and established itself as a discipline in its own right: that of information and knowledge management (Rezgui, 2001), and it is in this field that many of the current best practices lie.

Despite the interest and the effort put into knowledge management by many leading companies, the discipline is still in its infancy (Rezgui, 2001). Many practitioners and researchers have acknowledged the limitations of current approaches to managing the information and knowledge relating to and arising from a project (Choi & Ibbs, 1995). Some of the key reasons for these limitations are:

- Much construction knowledge, of necessity, resides in the minds of the individuals working within the domain.

- The intent behind decisions is often not recorded or documented. It requires complex processes to track and record the thousands of ad hoc messages, phone calls, memos, and conversations that comprise much project-related information.

- People responsible for collecting and archiving project data may not necessarily understand the specific needs of the actors who will use it, such as those involved in the maintenance of the building(s).

- The data is usually not managed while it is created but is instead captured and archived at the end of the construction stage. People who have knowledge about the project are likely to have left for another project by this time – their input is not captured.

- Lessons learned are not well organised and are buried in details. It is difficult to compile and disseminate useful knowledge to other projects.

- Many companies maintain historical reports of their projects. Since people always move from one company to another, it is difficult to reach the original report authors who understand the hidden meaning of historical project data. This historical data should include a rich representation of data context, so that it can be used with minimum (or no) consultation.
• New approaches to the management of knowledge within and between firms imply major changes in individual roles and organisational processes. While potential gains are desired, the necessary changes are resisted. (Rezgui, 2001).

As outlined in the previous chapter, the introduction of the Internet has had a significant impact on the construction industry. Further to this, much research has been conducted regarding layered architectures and middleware technologies (e.g. the member projects OSMOS, ISTforCE, DIVERCITY, GLOBEMEN), allowing the integration of legacy, proprietary and commercial applications widely used in the industry using an approach based on the Web Services Model. The sections below feature and expand on key developments in recent years in the application of ICT in the Construction sector, that are viewed as current best practice in the domain.

4.2 Document management systems

As stated in the previous chapter, most information used during the design-and-build process of a construction project is conveyed using documents, which are mostly exchanged, for contractual and legal reasons, on a paper-based medium, even when produced using computers. The challenge that the industry is facing today is the reuse of the knowledge and lessons stored within these documents. The latter are unstructured, poorly organised and embedded within the “black-box” that constitutes the document.

Document management has become a crucial issue within modern construction companies. The various solutions proposed by some software vendors have been revealed to be unsatisfactory, to a point where many leading construction organisations, with an advanced IT department, have undertaken the development of their own tools and solutions to support the production and maintenance of project documents. Even though such proprietary tools provide many helpful facilities, including support for document storage, retrieval, versioning and approval, they do not handle any semantics of the information being processed and therefore remain limited in their support of the end-user. In fact, construction project data and documentation (including full specification documents) constitute two fragmented information sectors where compatibility and interoperability are most needed. Moving these pseudo-sectors closer together to support construction-project documentation, as part of the life cycle of the building product is becoming an actual and urgent topic for standard bodies and the industry alike.

A survey undertaken within the ESPRIT Framework 4 Condor project (Rezgui & Karstila, 1998) revealed the following limitations of existing proprietary Electronic Document Management (EDM) systems used within the construction industry:

• Every partner within the project must use the same EDM system on a project in order to be able to access and share documents;

• The document’s semantics and internal structuring is not controlled by the EDM system; documents are handled as “black-boxes”;

I.E. WILSON and Y. Rezgui, 17 December 2003
• The EDM system does not support document cross-referencing or semantic linking;
• Security is always an issue – it is not as easy to implement as for printed documents; EDM systems require improved user authentication and document protection;
• The EDM system is not integrated with proprietary and commercial applications used within the company (e.g. CAD applications and word processors);
• Most end-users in the construction industry are not computer-literate. EDM systems lacking user-friendliness, or used in a maladapted environment (e.g. with network-communication problems), discourage the user from using the EDM system.

Several projects have tackled the crucial problem of document management, including RATAS (Bjork, 1993), ATLAS (Bohms et al., 1994), DOCCIME (Rezgui & Debras, 1995), and CONDOR (Rezgui et al., 1999). In addition, many commercial web-based EDM systems are now available. These include ProjectNet, BidCom, Evolv, and Buzzsaw. These systems provide document and workflow management services across the Internet. A new generation of EDM systems is also available today that offer advanced information management functionality, including:

• Ownership, rights and responsibilities: each actor is assigned a specific role (or roles) in the project, through which he or she interacts with the project information base;
• Versioning of information: a mechanism used to keep track of all the states in which an object has existed, including its current state;
• Schema evolution: allowing the underlying conceptual model used by the project actors to be altered, and to evolve over time, without affecting the overall consistency of the project information base;
• Recording of intent behind decisions leading to information: providing support for recording the factors that influence decisions, leading to information being produced or changed;
• Tracking of dependencies between pieces of information;
• Notification and propagation of changes: ensuring that objects and actors are kept informed of relevant changes introduced to the project information base.

We can today claim with confidence that EDM solutions are increasingly being used on projects and within companies in the Construction sector. They are, however, mostly used in medium and large organizations. There is a growing tendency for small companies to use these solutions on projects, mainly when provided and imposed by the Client.
4.3 Product data technology

Product modelling is an important step towards the integration of information across the various disciplines of an industry, including construction. A comprehensive description of ongoing effort in the area of product modelling can be found in (Eastman and Augenbroe, 1998). After over fifteen years of product-model development through STEP (ISO 1996) and more recently the IFC (IAI 1994), leading companies from the Construction industry have now started to embrace this technology, and the concept of model-based applications is now slowly being established.

It is worth mentioning developments led by Finish organizations, including Granlund and YIT from the Construction sector; and, Solibri from the ICT industry. Granlund and YIT can be seen as typical pioneers in the use of Product Technology, and can be referred to as success stories in this area. Similar developments in other parts of Europe are also expected in the near future thanks to the various IAI Chapters, and dissemination efforts (including in projects such as ICCI, prodAEC and ROADCON).

4.4 Groupware systems

CSCW (Computer Support for Cooperative Work) is more generally concerned with the introduction and use of groupware systems to enable and support teamwork. Groupware deals with highly unstructured data, including text, images, graphics, faxes, mail and bulletin boards. Groupware solutions include, traditionally, a subset of the following system components: workflow (task scheduling), multimedia document management, email, conferencing and shared scheduling of appointments. A recent survey of groupware constituent technologies (Zarli et al., 1998) reveals a lack of homogeneity, and a diversity of applicable de facto standards and APIs from the leading groupware vendors.

Groupware has the potential to flatten organisations and remove layers of bureaucracy. Groupware helps manage and track the project lifecycle throughout its various stages. It also allows the actors collaborating on specific tasks to exchange ideas and synchronise their work. It offers the potential to keep track of the project memory and record all its “learned lessons” in a way that promotes reuse. One of the important constituents of groupware is workflow. Workflow helps bring the information to the people who can act on it. It coordinates existing software and tracks the processes and helps to ensure that activities are performed by the right application undertaken by the right actors that have the right skills.

Groupware systems are already in use in many large companies in the Construction industry. The solutions being deployed include Lotus Notes. Furthermore, as highlighted in the OSMOS project, there has been a growing tendency for larger companies (including OTH in France and Granlund in Finland) to develop their own integrated groupware solution that is more specific and tailored to the needs of the Construction industry. In addition, with the wide development and acceptance of the Internet, solutions are today available from leading ICT vendors that can be rented and configured to the needs of the organization and / or project team. These solutions tend to adhere to the web services model. This is an area that is expected to develop in the next few years.
4.5 Decision support systems

Since the introduction of knowledge-based systems (KBS), numerous implementations have been undertaken and deployed in various industries, including construction, with varying levels of success (Levitt & Kartam, 1990). The UK department of Trade and Industry reported in one of its surveys (DTI, 1992) over 2000 knowledge-based systems deployed in business operations in industry, including manufacturing. These systems worked fairly well on problem domains that had an explicit model-based representation implemented through rules or objects.

However, as reported in (Watson and Marir, 1994), developing KBS without an explicit problem-domain model remains problematic. That is where other forms of reasoning, including case-based reasoning, have been explored. Case-based reasoning organises the structured archival of past experiences for future potential reuse. These experiences, commonly referred to as cases, are archived along with their unique domain characteristics expressed through well-defined indexes that describe the essence of the case (Watson & Marir, 1994). The success of this type of reasoning is largely explained by its simplicity, along with its similarity with human problem-solving mechanisms. Case based reasoning (CBR), compared to knowledge-based systems, provide many advantages (Watson & Marir, 1994), including the following:

- It does not require an explicit domain model and so elicitation becomes a task of gathering case histories;
- Implementation is reduced to identifying significant features that describe a case;
- CBR systems can learn by acquiring new knowledge as the number of cases increases.

CBR is still in its infancy in the construction domain. Several studies and prototype implementations have been proposed which highlight the benefits of decision-support systems using CBR techniques (Rezgui & Farhi, 1997; Farhi & Watson, 1995).

Most available knowledge-management systems (including KBS and CBR) rely on users’ input to orchestrate the information and knowledge discovery and elicitation. This is, however, becoming increasingly complex, as the electronic sources of knowledge are vast and rapidly growing with the successful deployment of IT systems within organisations. In addition, these systems have limited collaborative functionality and do not encourage information and knowledge discovery (Berney & Fernley, 1999) – they require the user to have a clear idea of the appropriate search terms. Such systems also require the tacit knowledge giver to be able to clearly articulate their knowledge and experiences. Prior to the introduction of technology to facilitate collaboration, an appropriate organisational culture must be in place to make use of the technology effective (Skyrme, 1999). This is an area where the agent technology can provide potential solutions. The usefulness of the application of the agent technology has been highlighted in (Bradshaw et al., 1997).

However, most agent-based systems available today operate on proprietary frameworks. They make use of proprietary underlying models and legacy script languages, and target corporate
proprietary and legacy databases. This results in limited application interoperability, poor integration in large-enterprise information systems and limited ability to extend (e.g. by direct integration of other pre-built components not based on the same agent network) and to follow the market evolution (Zarli et al., 1998).

Many medium-sized and large companies have developed their own in-house decision support systems. Some of these utilize what is currently known as “Best Practice Databases”. This is an area that is expected to expand and be widely adopted by the industry.

4.6 Data warehousing solutions

Data warehousing emerged as a result of two major developments in information and communication technologies: improvement in relational database management systems, and advances in middleware products that enable database connectivity across heterogeneous platforms (Hackathorn, 1993). On the other hand, there was increasing demand to separate informational processing (designed to support decision-making based on stable historical data) from operational processing (designed to run businesses in real time based on current data) (McFadden et al., 1999). Moreover, a data-warehousing solution proceeds by first extracting data and information from a variety of distributed operational systems and organising it in a centralised repository, then adding value to the extracted data through cleansing and transformation that improve its quality and consistency for exploitation by decision-support applications. As a result, a data warehouse has the potential to reduce drastically the need for important resources in order to filter useful data from confounded informational and operational information.

Data warehousing solutions can be found today in the Construction industry in what is more commonly referred to as Knowledge Management solutions.

Data warehousing is a promising technology that lends itself to the latest developments in relational database-management systems. A variety of end-user interfaces are today available from the leading database vendors (ORACLE, SYBASE, etc.) to access and analyse decision-support information stored in the data warehouse. These tools are commonly known as OLAP (On-Line Analytical Processing) applications. They provide users, including decision-makers, with a set of graphical tools that give a multidimensional view of their information base.

4.7 Mobile services

Mobile services refers to a technology that is being used to connect mobile terminals and devices (like mobile phones or PDAs) to the enterprise information systems. For modern businesses it is essential, if not vital, to allow actors to keep contact with the (virtual) enterprise information systems. As regards the Construction sector, there are many activities that cannot be undertaken with the classical desktop computer (too cumbersome to easily move around) and traditionally wired (fixed location) communication networks (Zarli et al., 2003). Typical examples are all activities around building construction sites, which require high mobility. Moreover, SMEs are in particular to be targeted as mass end-users of mobile
applications and services: this especially means that there are requirements for configuration and maintenance according to the individual wishes of particular end-users, connected to potential personalized “e-workplaces”. A detailed example is for instance, management on a construction site of time spent by employees, current status of stocks and deliveries, quantity surveying, etc., but it could also be enhanced mobile services for monitoring and decision making at the construction site.

Why should we be confident in the future of mobile services? First of all, today, numerous devices are at the disposal of mobile workers: mobile phones, GSM/GPRS terminals, PDAs, “electronic slates”, e-books, and wireless laptops. Moreover, standards and protocols are progressing: for instance, GPRS has many advantages towards GSM, with improved bandwidth, new mode of billing (based on packets), and less sensitivity to interruptions of the service, thus improving the Quality of Service (QoS). Two kinds of servers can be considered: Wireless Delivery Servers, which fundamentally manage the dissemination of information contents towards wireless terminals, and Wireless Synchronization Servers, which allow synchronisation of information between wireless terminals and central information servers, thus allowing the users to potentially work locally without having a permanent connection. Some systems provide users with a combination of both.

Because of the lack of a permanent connection, the main issues are: smooth access to information, managing of heterogeneity of terminals and communication protocols, integration to the already existing technologies and information tools within the enterprise, dealing with applications that have to connect to light or heavy clients (including the identification of various levels of QoS according to the type of applications or terminals), and even more specific to the construction sector, the management of potential huge set of data and information to be conveyed. Other issues are security and reliability of data: security is about protecting and encrypting flows of information between servers and mobile devices, reliability is again connected to the size of huge data flows to be potentially exchanged, and the issues of partial loss of information, or information that could have been corrupted. Overall, mobile computing leads to more complex architectures for information systems, and there is still clear needs for RTD on integrated service systems embedded in Web-oriented platforms providing an infrastructure for “ambient intelligence” for mobile workers, virtual desktops, information filtering according to some context determination, etc.

4.8 eCommerce and eBusiness Solutions

This is another area that is increasingly becoming common practice in the industry thanks to the wide adoption and development of the Internet. Companies are now offering their services through their corporate portals providing means for electronic transactions.

4.9 Case study from OSMOS

In the requirements capture stage of the OSMOS project, the methodology employed included identification of information and process inefficiencies within the industrial end-user organisations. The OSMOS concept developed throughout the project was realised as a real
world solution by the end of the project in response to one of these information and process inefficiencies, and implemented by the Finnish OSMOS partner Granlund. This section offers a description of the exploitation efforts Granlund made, which serves as a good example of best practice from the results of one of the ICCI member projects.

4.9.1 The situation at the beginning of the OSMOS project

At the outset of the OSMOS project (early 2000), Granlund held a strong position in the Finnish market with its Windows-based solution for technical facility management (FM), Ryhti. There were over 200 installations of the software, mainly in Finland but also in Scandinavia, the UK, Germany and Hungary. Many of the customers were big Finnish building owners with hundreds of buildings, and in some cases in excess of a thousand. Characteristic to these Windows-based installations, were large FM databases with a limited number of users (1-20 people), the software typically being used over a local area network (LAN).

Ongoing trends in technical FM include outsourcing of services to maintenance companies, the use of FM consultants, and an increasing need to distribute FM services to a larger audience. These trends made the use of LAN-based services problematic and Granlund realised that the use of the Internet in combination with the OSMOS concept offered a solution to the problem by allowing new and existing Ryhti customers to set up virtual enterprises for all parts of the FM process.

4.9.2 The current situation

Granlund’s implementation of the OSMOS concept is called RyhtiWeb and it is fully compatible with the existing Ryhti platform. RyhtiWeb is a direct result of Granlund’s participation in the OSMOS project and enables customers to set up FM-based virtual enterprises in an intranet/extranet/internet environment. RyhtiWeb has incorporated the central concepts from the OSMOS models, i.e. the ability to register any third party service to the VE and control the access to both data and services through a role-based scheme. RyhtiWeb also enables entities to be linked, i.e. cross-referenced across service boundaries.

By the end of February 2002, Granlund had installed RyhtiWeb to six existing Ryhti customers in Finland and Germany. Granlund also has a partnership with an application service provider offering RyhtiWeb to smaller customers or for a shorter period. The current RyhtiWeb customers are presented in Table 2 below.

Currently the main interest in the OSMOS concept among customers is its ability to provide role-based, location independent access to FM services and data for a large number of users. The FM Helpdesk service is a typical example of a service that involves interaction between a large number of users holding different roles.
<table>
<thead>
<tr>
<th>Company</th>
<th>Profile</th>
<th>Project Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senaatti Properties</td>
<td>Senaatti Properties is a government owned enterprise responsible for managing and letting the property assets of the Finnish state. The property stock includes university, office research, and cultural and other buildings.</td>
<td>The FM database contains over 2000 buildings in Finland.</td>
</tr>
<tr>
<td>Elisa Communications</td>
<td>Elisa Communications is a leading telecommunications company in Finland and employs 8000 people. The company provides fixed network voice, data and internet services for residential and corporate customers. The company’s networks host over one million fixed telephone and over 1.3 million mobile subscriptions.</td>
<td>The FM database contains 400 office and telecommunication buildings.</td>
</tr>
<tr>
<td>Wärtsilä</td>
<td>Wärtsilä Corporation is the leading global ship power supplier and a major provider of solutions for decentralised power generation and of supporting services. Wärtsilä employs around 10,000 people</td>
<td>Hundreds of thousands m² of industrial buildings.</td>
</tr>
<tr>
<td>Nokia</td>
<td>Nokia is the world’s leading supplier of mobile phones and a leading supplier of mobile, fixed and IP networks. Nokia has 18 production facilities in 10 countries and research and development in 15 countries around the world. Nokia employs around 54,000 people.</td>
<td>Hundreds of thousands m² of industrial buildings in Finland, Germany and Hungary.</td>
</tr>
<tr>
<td>The Civil Aviation Administration</td>
<td>The Civil Aviation Administration maintains Finland’s network of airports and the air navigation system. CAA’s airport network consists of 25 airports and the organisation employs 1,872 people.</td>
<td>Hundreds of thousands m² of national airport, aviation and office buildings.</td>
</tr>
<tr>
<td>Tapiola</td>
<td>The Tapiola Group is the largest mutual insurance group in Finland.</td>
<td>Hundreds of thousands m² of office buildings.</td>
</tr>
</tbody>
</table>

Table 2: Granlund’s current RyhtiWeb customers

While most of the customer companies are using only various FM services through RyhtiWeb, Senaatti Properties is focusing on integrating FM and electronic document
management (EDM) services through RyhtiWeb. Senaatti Properties is using a large number of external building consultants to produce maintenance plans and reports of the building mass located all over Finland. Maintenance reports consist of a group of textual and graphical documents related to a specific building describing both short and long-term maintenance activities required. The goal of Senaatti Properties is to utilise RyhtiWeb as an extranet entry point to the FM and EDM services so that the external consultants could store their maintenance plans directly into the system, thus creating a link between buildings and documents. The RyhtiWeb browser would provide a logical view to the building data and the EDMS would act as a document repository. Through a role-based access scheme the data would be accessible both to the organisation’s own personnel and to users from external organisations.

4.10 Business processes

The ICCI member projects are all aiming to develop innovative solutions to construction problem areas, with a technology focus that is state-of-the-art, and if implemented would constitute best practice with respect to ICT in the domain. Within each of the projects considerable work has been conducted in requirements analysis and the formulation of business processes that will be supported by the respective solution. In each case user scenarios have been elaborated, some of which then form constituent elements in user trials/evaluation of the solutions. These user scenarios have been collected, integrated and mapped to AEC industry processes via the Generic Design and Construction Process Protocol. This important early result of the project is detailed in (Katranuschkov et al., 2002) – deliverable D11 of ICCI.

The results from the projects cover a large conceptual base, providing test-bed or pilot examples on a generic level. Whilst field-testing or field trials are attempted in each project, these are necessarily limited in their approach due to time/resource constraints. Equally, it is noticeable from the deliverables produced within the projects that such trials tend toward a technology focus rather than the ‘bigger picture’ in terms of human and organisational issues. Examples of such issues here include real user acceptance of the introduction of new technologies, understanding and acceptance of the changes such solutions may involve, the importance of good employee relationships, supportive organisational culture and user involvement throughout the development of the solutions, recognition of the needs for training, coping strategies, etc. All of these aspects would require evaluation in terms of definition of and inclusion to a business strategy for the sector.

Furthermore there is little evidence of pragmatic measures being made in terms of assessing the potential cost/benefits of the technologies being developed, quantifiable assessment of potential improvements in efficiency, or actual investment that would be required for organisations wishing to implement resultant technologies.

As noted (Katranuschkov et al., 2002), virtually all existing process models focus inwards. That is, they concern themselves only with the specifics of the process with which they are concerned. There is little evidence of processes that focus outwards and that attempt to use developments of (and integrate with) other existing models. The facility to focus outwards is
not well supported by popular diagramming notations such as IDEF0 and UML activity diagrams. However, UML activity diagrams do support the concepts of interdisciplinary communication that is a fundamental requirement of building construction work. GPP on the other hand does provide support for integration of process models by formalising stages and activity zones. The results will allow definition of a reference process model for the industry and can greatly facilitate the clear recognition of industry requirements and needs related to current and future ICT efforts.

The efforts in the projects, captured by the report (Katranuschkov et al., 2002) do however constitute best practice in terms of modelling user scenarios, which will be of particular benefit to developers in the industry. As such, therefore, these issues should also be considered within business strategies for the future of the sector.

4.11 Summary

The technologies reported in this section give the reader an overview of available tools and methods that may be used to work towards business best practice. As noted above however, best practice is not prescriptive, therefore the use of any/all such technologies will benefit different companies to varying degrees. Indeed, there is a real risk that the costs, both human and financial, may be either prohibitive or even damaging to any organisation that embraces them without first considering their real business needs. It should also be noted that the above is not exhaustive, as such an exercise is outside the scope of this report. Further advances and information regarding ICT use in the sector can be gleaned from the ICCI deliverable D222: ICCI Market Watch (Cerovsek and Turk, 2003).
5. The human factor

Having briefly presented some of the technologies now commonly in use in the sector, this chapter presents results from the available research in human and organisational issues in construction. These results are based on EU reports, facts from the literature and other reports and results from the participating projects.

5.1 General issues

The construction industry currently faces many challenges as a result of new technologies and materials, different operational processes and intensifying cross border competition, as well as changing conditions in climate, demographics and lifestyle (Foresight, 2001). These changes have an effect not only on the construction industry as a whole and its working practices but also on personnel functions and people management. Despite the fact that the construction industry continues to be one of the largest providers of jobs (even in the depth of the UK recession in the early 1990s, for example, it employed more than 1.5 million people), in terms of people management and development construction still faces many problems.

In the UK the Movement for Innovation (M4I) was set up to improve construction industry in terms of value for money, profitability, reliability and respect for people through the demonstration and dissemination of best practice and innovation based on recommendations of the Construction Task Force (CTF) outlined in ‘Rethinking Construction’ (DETR, 1998). The CTF stressed that ‘If the industry is to achieve its full potential, substantial changes in the culture and structure are also required to support improvement. The industry must provide decent and safe working conditions and improve management and supervisory skills at all levels.’

More specifically, the Foresight report (Foresight, 2001) identified some issues, which need consideration aiming at specific actions:

- People availability. With a reduction in population growth there is a danger of a shortage in people availability for the future
- With an ageing population re-skilling has become an issue
- Lifelong learning requires investment and commitment by employees and companies, as well as the industry and Government
- An accreditation scheme for workers could acknowledge health and safety awareness and skills and knowledge capability
- Web-based platforms are already facilitating knowledge management
• Establishing vertical and horizontal skills alliances within and across different disciplines in construction industry education and training could foster increased collaboration and innovation for the future

• A consequence of the industry having many small individual businesses is insufficient critical mass and motivation leading to a lack of investment in training and research and development

• There is an imbalance of ethnic and female representation in the industry which may be due to the perceived image of the industry

• A company’s people are its most valuable asset, yet the assets of human knowledge are not valued on the balance sheet. These may be included in take-over valuations and reflected in share prices, but are mostly undervalued

• Improve the image of the industry and you invest in the quality of the people entering it.

Four main themes emerge from the above list:

• Health

• Safety

• Diversity in the Workplace and

• Learning, training and development

These four broad categories were also considered important by other working groups in construction such as the ‘Respect for People’ working group (DETR, 2000), which analysed problems and issues regarding people management in the construction industry and suggested actions.

Construction workers suffer from poor occupational health risk Management. The poor health record of the industry is considered as an obstacle in attracting qualified people and it is responsible for the bad image of the sector. Apart from these negative consequences, a poor health record has an impact on employee satisfaction, staff turnover, absence from work, and working hours. The sector also suffers from a poor safety record, which also has a direct impact on its image and its ability to recruit and retain people. There was a 26% increase in the number of fatal accidents in the industry in 1999/2000 whereas all other sectors showed a decrease. The ‘Respect for People’ working group suggested the following actions in order to deal with health and safety problems:

• Adoption of HSE targets (Health and Safety Commission) as a minimum

• Development of best practice guidance
• Development of pan industry data to gain figures on the nature and the scale of occupational health difficulties and advances

• Support the HSE’s work on developing good management practice for a range of causes of stress

• Meet the targets set by the DETR and the HSE in ‘Revitalising Health and Safety’

• Measurement of incidents as well as accidents

• HSE data is categorised by the type of accident, but not yet by other basic diagnostics such as cause, type of employer, procurement/contractual arrangement

• Involving the workforce in safety consultations (safety circles, task safety talks and ‘roving’ safety representatives)

• Improvement in the safety competence of site managers and operatives and the development and registration of a set of common core-competencies

• Provision of injury and death benefit insurance for all employees

• Implementing a safety culture

The report also addressed issues of diversity in construction indicating the low percentage of ethnic minority and the high percentage of white male employees. The issue of diversity is closely linked to issues of equality, considering the fact that greater diversity cannot be achieved without equality of opportunity to enter and remain in the industry. Research has shown that construction companies that invest in equal opportunities are more likely to invest in people’s training and development (Michielsens, Clarke and Wall, 1997). Investment in people has to be seen as part of an effort to change the current climate and culture in order to deal with the bad image of the sector.

5.2 Training

There is a need for the individuals in the workforce to continue to learn, update and add to their skills in order to remain employable and add to the competitiveness of the construction sector. The CITB Construction Employment and training forecast of January 1999 anticipated growth in the industry from 1.38 million personnel in 1997 to 1.48 million in 2003. This increase shows a greater need for new recruits into the industry. However, causes for skill shortages are not only due to recruitment problems. As Table 3 below shows, the construction sector faces many problems with people development because of continuous change in working practices, new technological developments, lack of training and learning, and poor people management.

Lifelong learning is considered as a critical success factor in order to support cultural changes. It can also attract and retain young and qualified people to the industry. The ‘respect
for people’ working group indicated a number of factors in order to encourage learning and development in the construction sector including:

- Relaunching the Investors in People scheme
- Identifying and promoting best practice projects with the aid of the CITB and the NTOs (National Training Organisations)
- Code of Training Practice to encourage clients to favour firms that have systematic workforce development programmes in place
- The Construction Industry Learning Network

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<th>Craft and skilled</th>
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<th>Clerical and secretarial</th>
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*Table 3: Causes for skills gaps in five construction occupations, CRISP, 2000*
5.3 Change management

The construction sector is facing more changes than ever before. As construction companies try to remain competitive, they are reorganising, re-engineering, downsizing and implementing new technology. According to (Lowe, 2001) there are many drivers of change in the construction sector and its supporting industries. These include:

- The general movement towards industrialisation, prefabrication and off-site construction encapsulated by ‘Rethinking Construction’ (DETR, 1998).
- Concern for the Health and Safety of employees in the construction industry.
- Changes in the structure of the industry through the processes of amalgamation and take-over, and in the nature of training for those working within the industry.
- The Europeanisation of the construction industry, both as a result of restructuring and as a result of the introduction of the single European Market.
- The process of economic growth, which, if it continues indefinitely even at 1% per annum, will lead to more than a 60% increase in economic activity by 2050 and to more than a two-fold increase by 2080 compared with the present.
- The impact of the far-reaching measures that are likely to be needed to control the emission of carbon dioxide and to control other environmental impacts from the built environment over the next 20-50 years - climate change mitigation.

In attempting to cope with change processes, it is important for construction companies to examine available tools, methodologies and training materials in order to design, implement and evaluate a change programme. Tools, models and methods of change are similar in concept and present many commonalities (Senge, 1999). (Lewin, 1951) suggested a three-phase model of change-unfreeze, move, refreeze; also, Beckard and Harris (1987) analysed a three-phase model indicating that complex organisational change can be conceptualised as a movement from the present state to a future state (Figure 3 below). The most important phase is the transition state which analyses how the company will move from the current state to the future one. As a result, change is a matter of assessing the current situation, developing the appropriate strategy and vision, and designing the change process.

The research carried out in the ICCI member projects, and indeed within the IST programme as a whole, is predominantly concerned with advanced tools, methods and technologies, many of which may not become usable within the lifecycle of a specific project, nor maturely developed for adoption in the near future. This, of course, is natural as such research is forward thinking and aims to pave the way to major changes in working in the medium- to long-term future. The human and organisational issues still remain, however, and indeed in order to ensure that companies can take advantage of the opportunities emerging from these advances in the future, change management issues will also remain. It is clear that managers need to ensure that their organisations understand the need for change, that they recognise the human element inherent in introducing change, and develop strategies to cope with change.
Whilst the potential gains anticipated through proper adoption of advanced ICT are desired, it is quite common for the necessary changes to be resisted.

![Diagram of a three-phase model](image)

*Figure 3: A three-phase model (Beckard and Harris, 1987)*

### 5.4 Teamwork

The vast majority of people in the construction sector work as members of teams, which are increasingly virtual in nature. Results from OSMOS (Wilson, *et al.*, 2002) show that the vast majority of people (86%) work as a member of a team or teams. Furthermore, 84% of the participants to the research said that they work as a member of a team on a daily basis. These figures are perhaps not surprising given the nature of construction work, but it is important to analyse how people work together in teams, their views about teamwork, and common problems they face. Teamwork is a cornerstone of the principles behind not only the OSMOS approach to the VE, but also many other research initiatives including those within ICCI.

The OSMOS results showed that the majority of people felt positive toward team working, though a little over half (53%) of the respondents indicated that they faced problems in teamwork. The responses were grouped in the analysis process, and were found to fit within three broad categories:

1. *Information* – factors including distributed information handling, managing information, and lack of information.
2. *Organisation* – factors including time scheduling, and meetings.
3. *People* – factors including communication, availability of people, and individualism.
Some of the respondents related that they had suffered no problems with teamwork, or ‘none worth mentioning’, and considerably more included factors in the Information and Organisation categories. A significant proportion of the answers could be categorised into the people category. Availability of people was the most common problem, poor communication, progress reporting, and finding the right team members were also included. Surprisingly, however, some people answered with problems including ‘differing opinions’, ‘lack of formality’, and ‘individuals causing trouble’. Once again this analysis shows that the emphasis is on human and organisational issues, but the references to individualism suggest that perhaps there is a lack of understanding in the methods and ethos of teamwork.

5.5 Strategic partnering

As the construction sector is characterised by collaboration between many stakeholders who work together in projects for limited periods of time, the issue of long-term partnering within integrated teams is becoming considered as a benchmark in best practice. Due to the complexity and long lifecycle of construction products, it is only natural that the current use of ICT is fragmented serving specific tasks, stakeholders, and lifecycle stages. Teamwork between distributed experts in participating companies is often supported by web-enabled file and document management systems with basic team collaboration support (however this is commonly project web sites). Collaborative virtual teams need to combine distributed competences via global collaboration environments that support cultural, linguistic, social and legal transparency.

The goal, through best ICT tools, is that distributed team members collaborate across organisational, geographical and time boundaries as if they were collocated. There is, however, still a lack of long-term partnering between actors, without which it will prove difficult to achieve results of proper ICT infrastructure and strategy adoption.

By encouraging the adoption of integrated teams, strategic partnerships can be formed that move from one project to another, thus maximising knowledge and efficiency. This paradigm is true throughout the supply chain as an enabler of supply chain management, a facilitator of integrated working, and as a measure to working towards the elimination of waste. The use of advanced ICT can support and enable the creation of integrated teams – and thereby strategic partnerships – at the optimal time in the construction process. Such partnering will make full use of the contribution each partner can make. The research shows, however, that it is still clear that too many construction organisations continue to believe that strategic partnering and integrated procurement are merely experimental techniques. It is essential therefore, to ensure that learning and training are provided, preferably with the application of training in real-time on live projects. Furthermore, within the learning process organisations should be made aware of the need to instil a culture of equitable risk sharing in a non-adversarial way.

5.6 Trust

Inherent in the majority of research projects’ evaluation results, is the clear need for trust. This is especially so in terms of the move towards ICT supported collaboration, the digital
Virtual Enterprise paradigm, teamwork (and indeed long-term or strategic partnering), and at a technological level in the tools being developed. Research into trust in construction (e.g. Swan, et al., 2002) has shown the importance of this cultural element further. Trust in organisations working together on construction projects is built up gradually over time within a project’s lifecycle, or across many projects in some cases. Naturally, there has to be trust at the outset of any collaborative effort, but it is natural human instinct to be wary of the unknown, both in terms of people and technology. Relationships with others develop and build over time, but construction projects can be unpredictable, and naturally over time problems arise. It is not at all uncommon for changes to occur at any stage within a project, producing either a need for, or an addition of, new information. It is vital that project teams have the ability, training, and understanding of how to work together to solve problems, and this is easier when a high degree of trust exists.

In terms of strategic management of construction projects, it is important for directors and senior managers to be aware of the importance of trust on a long-term basis. Swan et al. (2002) note that trust is linked to communications, actions, and outcomes, whereby the questions of whether or not communications can be relied on, whether or not actions are consistent, and whether or not outcomes are desirable, need consideration. Trust ultimately emerges where communicated information is reliable, people stand by their promises, and outcomes equal or exceed expectations. If people’s expectations are not met suspicion emerges rather than trust, and this is equally true in human/computer interaction as it is in human relationships.

The research also indicates that people generally tend to trust people rather than companies. However, the role of an organisation’s reputation is also important as to some extent construction is a relatively ‘small world’, with people constantly working with the same people over many years. Furthermore, trusting relationships are not just inter-organisational, but also intra-organisational. Effective teams are built when people have authority to make decisions and the information that they are passing between one another is honest and accurate. If an organisation does not trust its own people, its ability to build trusting relationships with other companies can be severely hampered. Equally, at a technological level, whether or not the people have trust in an organisation’s tools, systems, etc., will manifest the same results. This topic of trust at the level of the technology is examined in more detail in (Shelbourn et al., 2003).

### 5.7 Summary

The above issues and actions are supported by results from the ICCI consortium. The OSMOS research (Wilson et al., 2002) confirmed that the participating companies faced difficulties with information sharing, dealing with constant change, training and development, availability of staff, and the formation of teams. The following aims at synthesising these results by summarising the problems and exploring some solutions.

**Information sharing:** All end users face difficulties with information sharing because of technical and business reasons. It is important to note that a large percentage disagrees with shared knowledge databases mainly because of lack of trust and clarification of objectives.
a result, technology has to play a very important role enabling communications and
information sharing, supporting and improving business process and integrating services.
Moreover, the role of culture is very important. There is a need for building an organisation
that will support information sharing, and knowledge dissemination and will allow learning to
take place. Explaining the strategic vision, encouraging participation and involvement and
managing performance and linking it with the right rewards are three important steps toward
enhancing information sharing.

Organisational Culture and teamwork: Characteristics from the ‘participatory’ type of
culture such as flat structure, open communication channels, participation and involvement in
decision-making, enhance sharing of information and facilitate virtual teams. The analysis of
results indicated that teams in the construction industry face many problems such as lack of
availability and time planning. ‘Bureaucratic’ cultures cannot facilitate these cross-functional
teams and as a result, they can hinder the change process. An important finding from the
OSMOS research is related with motivation as part of the culture. High motivation levels and
job satisfaction are critical success factors in any organisational environment and even more
important in a virtual environment. Introducing interesting work and a choice of various tasks
within the same project are two important suggestions that were tested in two of the
participating end user organisations with good results.

Acceptance of change: It is very interesting to note that there were positive attitudes towards
change. Although some of the end users face continuous changes, some of which were not
successful, the results indicated a positive climate toward that direction. This finding may be
explained by the fact that there is dissatisfaction with the existing system that underlines the
need for change. However, there is a need for planned change in order to manage virtual
environments, which are characterised by continuous changes. It is important to note here that
age was found to be a crucial factor in all the end user organisations. As expected, younger
employees are able to use technology more effectively and they are more open to new ways of
working than the older employees. The difference between age groups in the frequency and
capability of the use of technology causes tension in all the participating companies.
Understanding people’s fears and concerns, encouraging involvement and participating, and
explaining the objectives of the change are the main targets in order to cope with potential
resistance to change.

Training: The results indicated that training is important particularly in project management
and software packages. On the job training is suggested as a feasible solution although there is
the problem of hectic schedules and lack of availability. Another suggestion is to build and
implement a training plan, which will take into consideration skills required for setting up
virtual teams. The tools, which can be used in the construction of a training plan, include:

a) Needs analysis

b) Job descriptions and team roles and responsibilities

c) The company’s strategic plans
6. Best practice business strategy

This chapter presents the emergent themes that should be addressed in development of best practice business strategy, and the critical success factors to be taken into account. The final section presents a proposed migration path to best practice, introducing the ICCI Best practice business strategy migration model, which can be used to identify opportunities for action and provide support for taking action through a series of phases.

6.1 Overview

The demand for continuous business improvement and innovation, new challenges for competitiveness, and new technological developments, all lead European construction companies to enrich and exploit their core competencies and knowledge. Confirming the need of strategic actions (especially dissemination and transfer of technologies) to improve the competitiveness of the construction industry and the quality of the construction products and services, the EC (European Communities, 1997) declared its intention, in co-operation with European industry representatives and Member States, to put progressively into place a structured Action Plan to implement strategic objectives and recommendations to improve competitiveness. ICT was clearly identified as an enabling tool in the construction process, and a (ECCREDI) Working Group dedicated to this topic edited a first summary report, dated 14 June 1999, which specified the nature of the challenge to be faced, IT-priority topics for the construction sector, and general recommendations. Among these was “a continuing need for research in this area in order to maintain Europe's leading position in the development of construction IT”.

6.2 Themes to address in development of business strategy

Analysis based on available documents from the ICCI participating projects and other documents from working groups in construction (Bartholomew, 2000; Foresight, 2001; CRISP, 2000) have indicated that there are three main themes regarding the development of business strategies for the construction sector now and in the future:

- Knowledge
- Communication
- Construction methods

**Knowledge:** Construction employees such as designers and contractors need to use a rapidly increasing range of knowledge and quantitative methods in order to meet customers’ requirements and expectations of better quality in products and services. These employees need to continuously be updated regarding new technology and working practices in order to remain competitive in a continuously changing and dynamic environment.
According to (Bartholomew, 2000) this can only be achieved if the construction sector emphasises:

- New commitment to lifelong learning
- New knowledge infrastructure providing just-in-time information delivery
- Much better use of corporate knowledge resources
- A new willingness to learn from experience
- Industry-wide knowledge sharing through benchmarking and electronic knowledge pools
- Much greater use of computer simulation and visualisation tools.

**Communication:** According to Bartholomew (2000) ‘The inefficiency, waste and product faults caused by poor co-ordination between clients, designers, specialist consultants, contractors, subcontractors and suppliers is already well recognised. The data-rich, fast and reliable communication provided by 21st century ICT is the glue that will enable the disparate organisations involved in construction to make truly effective teams for the first time’

It is very important for the construction sector to communicate more quickly and effectively in order to reduce waste, avoid re-work, offer cheaper and better products and services, and be cost-competitive internationally. The sector also needs to extend its boundaries to include clients and other companies such as banks and facilities management companies, in order to meet new design criteria like whole-life costs and sustainability, and to fit into new procurement systems such as Design-Build-Finance-Operate. ICT are able to facilitate these processes by providing online access to all stakeholders (clients, site managers, suppliers etc) offering more business opportunities to construction companies.

**Construction methods:** Developments in manufacturing industries, standardisation, controlled factory environments and mechanisation have increased productivity and quality to all levels. However, construction sites cannot follow this progress due to inefficient processes, which lead to slow results, accidents and dissatisfied customers. Today’s construction methods are incapable of delivering the expected performance according to business and lifestyle changes and the industry’s accident rate is increasing. ICT has a strategic role to play by continuing to improve both manufacturing and construction processes and by offering flexible and intelligent robots which will be able to carry out more on-site tasks with factory-like precision and efficiency.

Further to this initial analysis of business needs and recommended strategies, results from the ICCI member projects have helped to highlight the need for improving the use of knowledge, communication technologies and construction methods in order to address the strategic needs of the construction sector:
eConstruct showed that the construction industry has a great deal to gain from the exploitation of internet-based communication in eCommerce and eBusiness and contributed to the ways of communication across national and organisational barriers by improving the ways of transferring and sharing “knowledge” across different ICT systems. The eConstruct consortium worked towards narrowing this communication gap so that even small and SME construction companies can reap the benefits of using eCommerce and eBusiness effectively.

Divercity has shown the strategic importance of improving the Construction design process by concentrating on three key areas of the design activities: Client Briefing, Design Review and Construction planning. The project has shown the strategic need to integrate established Virtual Reality (VR) technologies with construction design activities in order to produce a design-lead “Distributed Virtual Workspace”. Addressing this need, Divercity developed coherent software architecture that addresses both the business needs of the users and emerging VR technologies.

ISTforCE has illustrated the importance of an Internet-based platform providing intelligent services and tools for an engineer participating in parallel in multiple projects. The use of this platform is the first step toward multi-project workflow management. From a strategic point of view, these capabilities can improve and broaden the work with respect to product modelling, workflow methods, middleware technology and the development of generalised knowledge communication and access methods.

eLEGAL has defined a framework for legal conditions and contracts regarding the use of ICT in project business. This project enhanced the capabilities of construction companies by developing and implementing legal support tools for the use of ICT in construction. Strategically, it is very important to be able to develop a business practice in which the use of ICT in inter-enterprise information exchange is contractually stipulated.

OSMOS set up and promoted value-added Internet-based flexible services in order to support teamwork. As noted above, the construction sector needs to be able to share and exchange knowledge and experience in order to support the deployment of Virtual Organisations. Both teamwork and virtual organisations constitute strategic elements for the development of the construction sector.

eCognos specified, developed, and tested an innovative open model-based infrastructure and a set of tools that promote effective and consistent KM (including capturing, organising, mining and disseminating) within collaborative construction environments. The evaluation results noted that a range of obstacles still need to be addressed including very variable user ICT competency and search techniques levels, and limited support for knowledge sharing within existing teamwork cultures (especially toward sharing across organisational boundaries).

6.3 Critical success factors and recommendations

Most of the ICCI member projects have carried out field trials/user testing, but predominantly this is with regard to usability and human computer interaction (HCI) issues. HCI issues are
important constituents in the development and evaluation of new technologies, and in terms of formulating a strategy for those organisations in the sector that are engaged in development there are recommendations to be found here. For example it is vital to involve and consult the people who will be using the new technology throughout the entire development process. Involving the users will also aid in the change process – they will be more likely to accept the new technology, feel that they have been a part of its development, and understand the aims and usefulness of it in their jobs from the outset. This approach actually works toward more fulfilling work (job satisfaction) because the users will perceive themselves as a part of the process. Also they will be more likely to help in improving the software/processes/efficiency in the future.

A further recommendation that may seem obvious, but evidence proves this not to be the case, is that companies should have an IT strategy. The IT-Barometer 2000 survey (Samuelson, 2002) revealed that in the Nordic countries 40% of the employees in the industry work at workplaces that have some kind of IT strategy. Mostly these are written strategies, though 8 percentage points of the 40 percent have an orally defined strategy. The majority of those who do not have any IT strategy state as a reason that they do not need one. Only architects and property managers state that they should have an IT strategy while the other categories (engineers, contractors, manufacturer/trade) mostly think that they should not. In the UK, Information Technology Best Practice (ITCBP) is an initiative (set up within the Rethinking Construction programme), which also advocates the need for IT strategies, offering practical advice to the industry through case study material.

The research evidence from the previous chapter also indicates that in order for organisations to achieve improvement through best practice, strategies should be created and used for coping with change, and learning and training. Indeed, from this perspective, such cultural issues could be added to the list above as extremely important themes to address in formulating business strategy.

In summary the key critical success factors towards best practice include incorporating within the general business strategy:

- ICT strategy
- Learning and training strategy
- Change management strategy

Furthermore, for organisations who are involved in the development of advanced ICT as enablers towards best practice it is strongly recommended that final (intended) end-user, or practitioner, participation is engaged throughout the complete development lifecycle.

### 6.4 Migration to best practice

New technological (ICT) advances, including the research prototypes developed via the ICCI member projects, offer companies in the construction sector a vision of the competitive advantage and other possibilities that the future promises. As a natural result of such advances, there is a gap emerging between current practice and this future vision. In order for
construction businesses to adopt a best practice *modus operandi*, the overarching requirement from the research lies in the realm of learning and training in the form of continuous professional development. The technology alone is only one change factor in this future of competitive advantage, however, which both promises and requires new working practices, organisational structures and cultures. Indeed, to fully understand the cultural and human issues inherent in change, whether such change involves introducing a new technology, computerising previously manual processes, or moving towards a long-term partnering strategy, etc., may require training that appears to be somewhat outside the scope of the ‘construction industry’ per se. As noted in the companion report to this document, the *ICCI Action plan on training in construction*, individuals at all levels need to take an active role in continuous personal development.

The characteristics and peculiarities of construction dictate that it is almost impossible to recommend a ‘best practice business strategy’ for the sector as a whole. For example, business strategy and recommendations offered to a large organisation with 1200 employees would probably have little meaning or value to, for example, a small enterprise of only 12 people, and vice versa. It is a simple fact that many SME in construction are managed by one ‘manager’ wearing several ‘business hats’ concurrently, though some critical success factors and human and organisational issues leading to best practice affect the entire sector. As was noted in section 1.1 ‘Best Practice’ is not, and indeed should not be, prescriptive. It would be virtually impossible to elaborate distinct business strategies toward best practice for specific stakeholders, and certainly within the resource limitations of an IST cluster initiative such as ICCI. In analysing the research results and considering these issues, however, it became apparent that in terms of the migration to best practice, a pragmatic model could be developed that will aid in the migration. Before presenting the developed model, the aforementioned critical success factors are further discussed.

### 6.4.1 ICT Strategy

There has been much research conducted in the area of need for, and creation of, ICT strategies, resulting in tools for organisational assessment and requirements, which can be self-administered within an organisation. (For example in the UK see the ITCBPP (Information Technology Construction Best Practice Programme) [www.itcbp.org.uk](http://www.itcbp.org.uk)). It is not the intention here to ‘reinvent the wheel’ as such – a practice that would be somewhat futile as in terms of construction stakeholders the formulation and use of an ICT strategy would not differ from those employed in other industrial sectors. The research suggests that having an ICT strategy, as part of the overall business plan, is not common within construction industry organisations. Within the work carried out in developing this document, several interviews were conducted with industrial partners from the various ICCI member projects, in which the interviewees were asked if they had an ICT strategy. It is interesting to note that whilst most did not actively employ an explicit strategy, they were increasingly aware of the prudence of such an initiative, and the interviewer was told that plans were in place to introduce one.

In acquiring and implementing ICT there are some basic questions that should be considered before taking action. These include ensuring that there is a full understanding of how the ICT will work for the organisation, what costs are involved, and clarity of the benefits in terms of
fulfilling business strategy and competitive advantage. A short ICT strategy should include and consider the following points:

- **Become an ICT expert** – learn as much as you can about ICT. This will help in making the right decisions later.
- **Lead from the front** – senior staff must set a ‘pro-ICT’ example.
- **Get everyone involved** – always consult the staff that will have to use your new ICT system: it is important that they support your strategy.
- **Establish clear objectives** – set well-defined goals and stick to them. This will aid in controlling project costs.
- **Get the best help** – support from outside the organisation should have project management experience as well as ICT skills. Is the project team large enough?

Further to basic ICT strategy provision it is also important when considering specialist tools and systems currently being developed to support virtual teams and the digital VE, that adequate support and training is available from the providers of such tools and services. It has been suggested in the research (and implemented in some cases – cf. section 4.9 above), that the potential for renting specialist services to organisations within a digitally enabled VE could counter prohibitive costs. (A further, interesting alternative paradigm has been put in place in the UK, however, in which Ove Arup developed its own document management product (called Columbus – see ITCBP case study IT015 on its development) because the market offerings had operational limitations and licences were expensive. Rather than engage in elaborate marketing, the product is now made available free of charge from the organisation’s web site. This has resulted in thousands of firms working with other organisations large and small, and all having a common exchange format).

Clearly, in introducing new ICT there is a learning requirement, which leads again to the need for a learning and training strategy as part of the business planning. On the first point in the above strategy, for small organisations the requirement for ICT training is likely to result in the person initially being trained subsequently becoming the trainer.

### 6.4.2 Learning and training strategy

The companion report to this document, the *ICCI Action plan on training in construction* (Rezgui *et al.*, 2003), covers in detail the development of a learning and training strategy for the sector. An eight-phase iterative methodology has been developed consisting of:

- Phase 1 – Awareness raising
- Phase 2 – Core business process analysis
- Phase 3 – Current skills analysis and mapping
- Phase 4 – Define/review ICT strategy
- Phase 5 – Identify skill gap
- Phase 6 – Identify/review new/existing roles and responsibilities
- Phase 7 – Plan and organise user-centred education and training
6.4.3 Change management strategy

As noted in section 5.3 above, it is clear from the research that managers need to ensure that their organisations understand the need for change, and that they recognise the human element inherent in introducing change. ICT advances, once implemented inevitably change process, working methods, etc. In order for changes to be accepted smoothly there are certain key points to consider:

- **Leadership and people** – Having the right people with the skills and willingness to change is an essential prerequisite. Committed leadership by project champions is needed to create a project team vision and encourage the new innovation. Such people should be identified from the outset and supported throughout. They are essential for anticipating potential conflicts and driving the initiative forward, whilst communicating the benefits and nurturing the vision.

- **Early involvement** – There is ample evidence that the earlier all the stakeholders to be affected by the change initiatives are involved in the process, the more certain acceptance and reduced resistance becomes.

- **Understanding people's fears and concerns** – Allow people to openly voice their concerns, and provide answers through participatory involvement.

- **Explain the objectives** – The true objectives of the change, once explained, understood, and envisioned as beneficial will be embraced rather than resisted.

In a nutshell, the key guarantors to successful change include commitment, involvement, and shared perception. Again, there has been much research carried out regarding change management, and it is apparent that change management itself is a candidate training issue for managers in many organisations.

6.4.4 The ICCI Best practice migration model

There is always scope for improvement in any company or organisation, regardless of its size, composition, and culture. The move towards best practice via implementation and use of ICT, together with inherent changes in working practices, methods and techniques is an exercise in change with a view to improvement. The key to successful improvement is through being constantly aware of new opportunities and an open-minded approach to innovation. However, ideas and theories simply remain as potentials and possibilities until action is taken. So far the previous sections have indicated pragmatic actions to take. But actions resulting in potentially significant change should not be made lightly. The model developed in ICCI and presented here aims to highlight the steps required to successfully implement most of the potential changes involved in embracing the emerging vision promised through new ICT and working methods.

The model emerges from an initially ‘commonsense’ starting point in which five phases of activity can be observed in sequence, producing a linear process. The five phases include:

- Phase 8 – Measure and evaluate progress
• Measuring,
• Diagnosis,
• Planning,
• Action, and
• Reviewing.

However, ‘reviewing’ the migration process should be a continuous activity of monitoring and evaluation. Through putting into place any course of action there will naturally be effects from that action or change. It is actually via the effects of the action that we can gauge whether or not the process is successful and beneficial. The fifth activity in the sequence therefore consists of observing and taking account of the effects, with review of the process becoming an ongoing activity. Continuous review of the process based on its effects thus forms feedback loops, creating an iterative or continuous process of improvement, rather than a simple linear sequence of action. Through explicitly observing the effects of the change, the reviewing process then acts to open up the ‘black boxes’ of the first four activities, allowing refinement, correction, or endorsement. From this thinking emerges the migration model depicted in Figure 4.

![Diagram: Best practice business strategy migration model]

The various phases are detailed below:

**Measuring** – Measuring your current performance is the best place to start in any change initiative towards best practice. By measuring current performance areas for improvement can be more readily identified. This will also provide a baseline against which to measure progress following the change.

**Diagnosis** – Following on from measuring current performance, the next step is to begin to understand why you are performing the way you are. This diagnosis may involve varying degrees of focus, for example focusing on a small number of areas in very great detail.
Planning – Having measured current performance and diagnosed the causes of your current performance, the next step is to plan what you are going to do. It is at the planning stage that you decide what improvement you want to make, how you are going to do it, in what time frame you will do it and how your progress will be measured.

Action – As noted above, nothing happens until you take action, so having planned what you intend to do, the next step is to make the changes.

Effects – The key to this phase is the observation of effects that arise from the course of action you have taken in making the change. This phase is very important, not simply as you need to be able to ensure that the desired effects have been achieved, but also to be aware of unexpected effects. The whole point of making some change, introducing a new technology, process or method, etc., is to bring about some intended effect. From the earlier phases of your migration strategy, the effects you desire should be clear and measurable in some way. What is important here is to recognise that effects that emerge from the actions in the process can fall into two categories:

- Intentional (or planned) effects
- Unintentional (or serendipitous) effects

If your activities in the earlier phases of measuring, diagnosing and planning have been done correctly and accurately, it should be clear what the effects are that you expect to occur. However, as with most planning we cannot be sure that all possible eventualities have been accounted for, and unintentional effects may emerge. The interesting point is that this is not necessarily a negative outcome, indeed many unintended effects can prove to be serendipitous and reveal flaws in the earlier phases, indicating a better way to proceed than we originally envisioned. By observing the effects, whether they are intentional or unintentional, positive or negative, the complete migration strategy can be continuously reviewed, with feedback to the earlier phases, and correction of those phases. In this way the change can be carefully monitored to ensure that we are progressing to the intended goal and improvement.
7. Conclusion and recommendations for future research

This report is the second (final) version of the deliverable D31 ICCI Best Practice Guide. Following a presentation of the characteristics of the construction industry, serving to place the research in context, the document highlighted current usage and common practice of ICT in the sector and a selection of the latest ICT developments. The focus of this document, however, is the human and organisational issues in construction ICT, with a view to making recommendations towards a ‘best practice’ business strategy. Results from the available research in human and organisational issues were described, from which themes and critical success factors emerge that should be addressed in strategy development. The final section presents a proposed migration path to best practice, introducing the ICCI Best practice business strategy migration model, which can be used to identify opportunities for action and provide support for taking action through a series of phases.

The characteristics of the construction industry play a large part in the shaping of research efforts for the sector, and increasingly in terms of producing usable and accepted technologies to support the key characteristics of distributed team working in a ‘virtual’ enterprise sense. Equally, however, some of the characteristics – e.g. the predominance of SME – also act as a moderating factor in achieving widespread acceptance and understanding of the results. In terms of human and organisational issues it is difficult to offer specific business recommendations without detailed and extensive research having taken place concurrently with the technological research and development.

This document offers a pragmatic methodology for practitioners to consider and use in trying to take part in the necessary migration from the current state-of-the-art in terms of ICT usage, to the future envisioned by so many technology research prototypes. Whilst the aim of such advanced technology research is not (and could not reasonably be expected to be) aimed at solving the immediate day-to-day and short-term problems faced by the industry, but is rather aimed at the medium to long-term future, it should be noted from works of the nature of this report that the ‘soft’ aspects of research should neither be ignored nor treated lightly. Throughout the process of analysis and research for this current document it was clear that there is still a definite techno-centric focus to the research projects. Whilst the developments being made from a technological standpoint are outstanding, in order to maximise the value of such developments it is vital that equal weight is given to human and organisational issues in future research work.

It is interesting to note that where such ‘soft’ issues are touched upon in predominantly technical projects, there is often a claim that an Action Research (AR) approach has been adopted. In its purest sense this is very rarely actually the case, as AR requires observation of change in real situations, with continuous evaluation and adjustment. Whilst such a methodology may be seen as high risk in the construction industry, especially considering the razor-thin margins to which many companies are tied, in terms of developing technologies with real future potential for widespread impact and acceptance, a more purist AR approach, with far greater practitioner involvement and evaluation should be recommended as a potential methodology for future research projects.
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