# Building, a Better Future: Major Results from the ICCI Cluster Project

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## Summary

To support research in the building sector and in order to help it move towards a new digital economy, the European Commission under the 5th Framework initiative, especially the IST programme, funded various RTD projects. The opportunity to bring these IST projects together was acknowledged so that stronger links can be created under a clustering umbrella and that, moreover, links of those projects with their RTD environment could be facilitated. This has been the objective of work carried out within the ICCI (IST-2001-33022) Cluster project. This paper introduces the main aims and objectives of the project, and then presents its principal outcomes. In a second part, it synthesises the underlying concepts, technology and tools that will make ICT-based Construction a reality in a near future, and gives recommended actions for the industry, the EC and the Construction ICT R&D in Europe, giving some benefit of this project experience to the three communities.

## 1 Introduction

Research and Development efforts and initiatives in the area of Construction Information and Communication Technologies (ICT) have traditionally been fragmented and very much subject orientated. Little emphasis has been put on long-term strategies that would create the right impact in order to enhance and change practices in industry and lead the way towards a sustainable knowledge-driven Construction that enhances needs and aspirations of individuals and society as a whole, in a fashion which is economically, socially and environmentally appropriate and sustainable. Within its framework of "SME dominant" industry and geographical dispersion, the construction industry is characterised by various challenges in terms of working practices and solutions. These include:

- Fragmentation, with no dominant actor to enforce ICT solutions on projects.
- Actors are involved in numerous projects at the same time, moreover on the basis of temporary and often short-term business relationships: project partners may never work together again.
- Poor communication between stakeholders during all life cycle phases.
- Information exchange within any construction project is mainly between actors other than the client and is not, therefore, contractually controlled.
- Difficulties to create a clear focus on end-user requirements amongst the actors.
- The industry is project oriented: this influences the incentives, accounting, etc. Any ICT must be deployable and profitable within one project to all/several partners.

The demand for continuous business improvement and innovation, and new challenges for competitiveness, must lead the European construction companies to enrich and exploit their core competencies and knowledge as best as possible. It is the role of the European RTD and it was the objective of ICCI project (IST-2001-33022 - *Innovation co-ordination, transfer and*

*deployment through networked Co-operation in the Construction Industry* - http://icci.vtt.fi) to pave the way in helping companies to achieve this vision. In all countries, construction is a low profit, low margin industry (compared to finance, IT, pharmaceuticals, etc.), with companies usually selected on the basis of lowest-cost. The tight business margins require that RTD be externally supported since companies (particularly SMEs) have little capacity themselves.

The ambition of the ICCI initiative was to build a cluster upon of a set of IST projects (*see next section*) related to IT in construction, to start paving the way towards a concerted support for the future implementation and deployment of new technologies in the Construction industrial context. The ICCI project, which subscribed to the vision of a globally networked economy that enables European construction companies (in particular SMEs) to increase their competitiveness in the global marketplace and improve the processes leading to Building products. It did so by (1) promoting the use and efficient deployment of ICTs to contribute to a highly competitive European Construction networked economy, and (2) reinforcing collaboration with standardisation bodies to ensure coherence in European technology deployment and in creation of a new open framework for fair competition and fast innovation.

## 2 The Main ICCI Objectives

As already mentioned, the ambition of the ICCI initiative was to build a cluster upon a set of IST projects related to IT in construction, with the following objective: 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 of R&D outcomes. The initial main ICCI related IST projects are presented in Figure 1 below.

| ***Acronym*** | ***Project number*** | ***Title*** |
|---|---|---|
| *OSMOS* | IST-1999-10491 | Open System for Inter-enterprise Information Management in Dynamic Virtual Environments |
| *eConstruct* | IST-1999-10303 | Electronic Business in the Building and Construction Industry: Preparing for the new Internet |
| *Divercity* | IST-1999-13365 | DIstributed Virtual Workspace for Enhancing Communication within the Construction Industry |
| *ISTforCE* | IST-1999-11508 | Intelligent Services and Tools for Concurrent Engineering |
| *eLEGAL* | IST-1999-20570 | Specifying Legal Terms of Contract in ICT Environment |
| *GLOBEMEN* | IST-1999-60002 | Global Engineering and Manufacturing in Enterprise Networks |

Figure 1: The initial ICCI member projects

These projects had common objectives, e.g. the use of the Internet and the improvement of construction competitiveness. ICCI concentrated on cross-fertilisation and harmonisation among these IST projects, kick-starting industrial dissemination and technology/services transfer, thus preparing for future industrial take-up activities. The general objectives have been to:

- collect, synthesise, consolidate and validate at a European level, the end user requirements and use cases/scenarios from projects, in order to lead to industrial requirements and some (set of) reference model(s) for ICT in construction;
- collect, synthesise, and publish ICT state-of-the-art in the fields of standards, technical advances and available commercial offerings, and to harmonise research and developments related to ICT infrastructures for construction projects;
- collect and synthesise information covering the integration of human, organisational and technical elements in construction projects to enhance the capabilities of the sector, leading to best practice guides about organisation development issues (e.g. team working, change management, etc.) and to action plans for training in AEC/FM;

- collect and assess the latest developments in the area of legal and contractual support for the use of ICT in construction. This included reviewing the technologies developed within the cluster projects to identify gaps and potential problems, and formulating recommendations and criteria for the integration of legal and contractual aspects in future developments of ICT tools;
- deliver large external dissemination (typically through conferences, seminars, workshops, exhibitions, online newsletters, user interest groups, etc) to inform the industry, and SMEs in particular, about state-of-the-art tools and methods in ICCI member projects, the usage of these and developing migration strategies towards adoption by SMEs;
- provide with future needs, strategy and implementation plans for IT in construction, integrating and consolidating the conclusions from the various activities into an overall strategy and roadmap, both for future RTD and industrial deployment of ICT.

# 3 Main ICCI Results and Outcomes

The ICCI activities have been undertaken according to the following main technical themes:

- T1: industry requirements and needs in the global eBusiness.
- T2: ICT infrastructures for construction projects.
- T3: human and organisational aspects for ICT in construction.
- T4: legal and contractual aspects of networked co-operation in construction.

The main deliverables of ICCI are shown in Figure 2 below, with their target audience. It is worth noticing that besides outcomes corresponding to the four themes introduced above, other deliverables relate to global dissemination (e.g. the ICCI book) or identification of future needs, strategy and plans at a European level for RTD in Construction ICT.

| Title of Result | Audience | | |
|---|---|---|---|
| | Industry | Research | IT Mngrs |
| Collected end users scenarios (**T1**) | X | X | X |
| Collected end users requirements and common structure (**T1**) | X | X | X |
| End User Requirements: Common Structure and Gap Analysis (**T1**) | | X | X |
| Assessment and continuous updates of end users requirements (**T1**) | X | X | X |
| ICT common glossary (**T2**) | X | X | X |
| ICT ontological framework and classification (**T2**) | | X | X |
| State-of-the-art in ICT standards & standardisation efforts (**T2**) | | X | X |
| Market watch (**T2**) | X | X | X |
| RTD advances and migration risks (**T2**) | | X | X |
| Synthesis of projects ICT infrastructures (**T2**) | | X | X |
| Guide for tools/services delivery (**T2**) | | | X |
| ICCI Best practice guide (**T3**) | X | X | |
| ICCI Action Plan on training in construction (**T3**) | X | X | |
| State-of-the-art review report on legal and contractual issues of ICT in construction (**T4**) | X | X | |
| Potential legal gaps and problems within the cluster projects (**T4**) | X | X | |
| ICCI vision for integration of contractual and legal aspects of ICT into networked co-operation in construction (**T4**) | X | X | |
| The ICCI Book | X | X | X |
| Strategies for Future RTD and Take-up | X | X | X |

Figure 2: The main ICCI deliverables.

ICCI has produced a substantial set of results that are difficult to fit within the scope of a single paper. All results are available through the ICCI website at http://icci.vtt.fi, and some have been presented in previous articles, e.g. (Kazi et al. 2003). This paper concentrates on a summary of the main results in each topic introduced above.

## 3.1 Industry requirements and needs in the global eBusiness

Objectives of this work was: (1) to collect, and consolidate business cases, user scenarios and end user requirements from ICCI projects, (2) achieve a synthesis of the findings and a gap analysis, and (3) define a reference model (through a process matrix capturing the collected data), including recommendations for future RTD efforts to the industry and the research community. This effort led to several reports, the key output of which is the Process Matrix approach, the result of a development effort started within the ISTforCE project and continued during the ICCI project where it was considerably extended and refined up to its present state, including a first prototype web-based database implementation (ProMAP). In short, the Process Matrix can be seen as a table that sets down a series of reference activities and, for each activity, identifies the project participants (actors) sending and receiving information, the communication requirements, the adapted standards for data and communication, etc.

The Process Matrix is evolutionary work, with potential further enhancements and modifications to meet new requirements and additional areas of application. Next planned steps of the work include (1) elaboration of a Reference Process Matrix identifying a range of possible generic and specific processes that might be used in ICT projects in the industry at large, (2) support to IFC development by improving the IFC process model and reinforce its usage, and (3) support to the dissemination of ICT standards. Through active membership in the IAI and in the EU prodAEC project, these steps are currently already being undertaken.

## 3.2 ICT infrastructures for construction projects

The overall objective associated to the identification of ICT infrastructures for construction projects was "to collect, synthesise, and publish ICT state-of-the-art in the fields of standards, technical advances and available commercial offerings, and to harmonise research and developments related to ICT infrastructures for construction projects". This was turned into the following actions:

- Identifying and structuring all the RTD themes shared by IST projects under ICCI;
- Developing and set-up a multilingual dictionary of terms related to the fields covered by ICCI;
- Creating an ontological base of the fields of ICT in construction;
- Providing with an up-to-date synthesis of market watch studies, existing standards and standardisation efforts, and RTD advances in the various fields targeted by ICCI;
- Realising a synthesis of innovative research paths pursued by the IST projects under ICCI as well as complementary expected results (e.g. models, APIs) and potential synergy;
- Realising a synthesis of projects ICT infrastructures;
- Organising technical workshops and meetings among projects under ICCI umbrella, as well as other project identified in the course of ICCI (and of potential interest for ICCI);
- Investigating ways to optimise future delivery of tools/services to construction companies and SMEs.

As it is not possible in a single paper to introduce all the results, we hereby introduce to the *ICCI ICT Infrastructures for the Building Construction Industry* report (Beheshti et al. 2003). Based on a survey amongst members of ICCI partner projects, one conclusion of the report is that there is little consensus on what constitutes the ICT infrastructure for the BC industry. An important finding is that while the BC industry is preparing for model-based ICT infrastructures, the bottleneck to achievement lies with incompatible software applications. Respondents see standardisation efforts as vital, but progress is still insufficient to make them commercially viable. The survey also reveals a shift towards knowledge-driven ICT infrastructures that are probably best suited to the culture and practice of the BC industry. This

has to be seen as one of the key reasons for ICCI to elaborate and launch the *CEN/ISSS Workshop for eConstruction* (see *www.nen.nl/wseconstruction*) drawing together the many efforts, initiatives, projects, organisations, companies and people that are currently active in research, development, application and standardisation to deliver "consensus specifications for an integrated suite of construction e-standards". This consensus is seen as a critical success factor to hasten the "evolution" in the European construction sector.

## 3.3 Human and organisational aspects for ICT in construction

There are many drivers for change in the construction sector. Through RTD projects, advanced technology prototype developments offer companies in the sector a vision of the competitive advantage and other possibilities that the future promises. To achieve exploitation of advanced ICT requires not only the implementation of innovative technologies but also new working practices, organisational structures and cultures, and there is growing recognition that the potential benefits of technical and process innovation can only be realised through individuals at all levels learning and developing a considerable array of new capabilities.

Therefore, organisational and human issues have been highlighted, among other issues, as key elements in enhancing the competitiveness of the construction sector, including training and professional development of human resources, in order to cultivate a stable workforce. This work has produced two major results: (1) an ICCI Best Practice Guide (Wilson & Rezgui 2003a), and (2) an ICCI Action Plan on Training in Construction (Wilson et al. 2003b).

ICT best practice is not easily identified through research projects that by definition tend to be working ahead of practice. Moreover, what suits the culture of one organisation may not suit another. Nevertheless, the report is thought provoking as it points to salient issues, technical and human, that impact best practice. Advanced ICT research shows, however that new working methods, processes, and techniques (e.g. for information and knowledge management and sharing) are possible, as evidenced particularly with the continued uptake of Internet technologies. Such advances entail change and it is clear that training is required not only in ICT but in ‘softer’ aspects of human and organisational management and in developing a culture of ‘learning’. The view is advanced that responsibility for such changes in culture lies at the management level of any organisation, regardless of its size.

The Action Plan on Training in Construction developed in ICCI provides a review of the key training needs for the construction sector with particular reference to the uptake and exploitation of new technologies and working practices, presents an action plan to address learning and training needs, and proposes an eight-stage iterative learning and training methodology. It will be of particular interest to managers in stakeholder organisations of all sizes throughout the sector, plus academic and research bodies intending to continue construction ICT research.

## 3.4 Legal & contractual aspects of networked co-operation in construction

Initial results have been a review of the general legal and contractual issues that impact the working models of the construction industry, mainly for the virtual enterprise (VE), and highlighted more than 10 major issues ranging from VE legal identity, intellectual/industrial property rights and interchange agreements to consumer protection, taxation liability and ICT implications. The led to appraise the necessary steps for integrating legal and contractual aspects into future technology developments. Ina second stage, the work has centred on producing an ICCI vision for integration of contractual and legal aspects of ICT into networked cooperation in construction. The aim was to provide a vision and a strategy to realise this vision of how using information and communication technologies in project based businesses may in the future be achieved in a legally and contractually valid manner. The target audience is construction stakeholders involved in construction project management and ICT usage.

The use of ICT in project-based businesses has already been extensively published, but not the legal and contractual aspects of this use. Though this is beginning to change (as can be seen in the research carried out by some recent projects), the overall objectives in ICCI have been to:

- direct people to considered legal and contractual issues of ICT;
- provide a review and define a vision of the future of the legal and contractual issues associated with the use of ICT in construction;
- integrate these aspects of ICT in construction into future ICT tool development;
- provide recommendations and criteria for the integration of legal and contractual aspects in future ICT tool developments.

To enable the realisation of these objectives a vision was developed, summarised as:

*"…to achieve trust & confidence in electronic transactions in project based businesses (i.e. construction) through the integration of the legal and contractual aspects in future technology developments…".*

To enable the vision to be realised, a simple methodology described in (Shelbourn et al. 2003) has been put in place, including a "Generate Conceptual Vision" stage that has been a detailed exercise involving studies from many sources. But out of eight major visions or roadmaps, as detailed in (Shelbourn et al. 2003), there was little or no mention of the legal and contractual issues associated with the use of ICT in the construction industry. The only publication of the eight that had any reference to these aspects of ICT was contained within the European ROADCON (Zarli et al. 2003). As this was the only mention of the legal and contractual issues in these visions there was much time spent studying this roadmap. This has led to a more detailed description of how the vision shown above can be achieved, and how the legal and contractual issues need to be further developed over a 20 year period to enable a legal framework to be fully integrated into future RTD developments for project based businesses in general, not only construction.

# 4 Building, A Better Future: Constructed by People with ICT Know-How

One of the major ICCI challenges (the results of which were perhaps most rewarding) was the production of a booklet highlighting some of the major problems faced by the construction industry and making an attempt to provide "snippets" of solutions to these problems through short focussed introductions to various technical streams. A difficult challenge indeed when the information was to be short, precise and addressed primarily to an industry audience with some ICT know-how. Within this section an overview of the book is provided in the form of "excerpts" from its chapters to provide the reader with an overall feel of the book. This is followed by short summaries of some selected chapters. These are chapters mainly from the introductory section, and the concluding section of the book.

## 4.1 Overview of ICCI book sections

### 4.1.1 An industry perspective of work

The focus of this booklet has been Information and Communication Technology. That is not a main focus of the construction industry, however, except in architectural design, engineering analysis and similar technically focussed activities for which computer software is indispensable i.e. a must! The perspective of the industry is work and the results of work, concerned for the impact of problems of process on time, cost and quality. Therefore the book starts with a case study of the performance of an anonymous but (largely) real project, through the eyes of the main contractor taking notes on issues like project teamwork, planning and reporting, control and management, change and – finally – the use of ICT.

### 4.1.2 Working together

The Industry is used to "working together apart" based on contracts, sub-contracts and supply relationships in design, construction and ongoing maintenance activities. Here some of the issues in terms of human, computer and business communication are presented - plus the legal framework of trust that is being put into place:

- Communication : Mobile phones, computers and PDAs allow site personnel to access anyone, anywhere rather than particular locations. In a way this closes a loop, because project masterminds can be at the construction site, just like the master builders of the past. And in fact present on several site simultaneously. Virtually, at least.
- Process management : The kind of workflow needed to undertake effective cross-border process management amongst virtual teams in construction projects presents not only considerable technical challenges but even greater cultural challenges. Timely preparation is key.
- eCommerce : The impact of eCommerce as part of eConstruction will be huge. One has only to look at customer-supplier relationships in other sectors – particularly retail and banking – to appreciate that.
- Legal issues : The use of collaborative environments has exposed unanswered legal and contractual questions, leading to concerns about trust and confidence associated with electronic transactions in construction projects.

### 4.1.3 Using and managing information

What are some of the technical developments that information handling is based upon? We address here the Web revolution and its future evolution, the integration of businesses, projects and software systems, the focus on "model-based" solutions, and the work to establish standards for electronic communication of construction knowledge:

- **Spinning the web** : A web of services … Software companies, big and small, will become service providers relying on the income from day to day use of their software rather than from the one-off sale of shrink wrapped software. Users will always have access to the very latest versions of software.
- **Integration** : Integration combines a set of "discrete cogs" into a working mechanism. For software systems, a framework is required that allows different applications to "interoperate" (i.e. cooperate or communicate) to deliver benefit to the industry user.
- **Model based information** : Objects are crucial to electronic collaboration. The different aspects of a product (building or part) are related together. Different disciplines contribute and extract those parts of the total information that are appropriate to them.
- **eStandards** : Standards are the building blocks of communication. You accepted the alphabet, the dictionary and the structure of language as a child – just accept these new standards (and encourage your software suppliers to do the same!).

### 4.1.4 A knowledge-centric industry

The construction industry has been a skill-centric industry since its early inception. Skills were passed on from one generation to the next. This concluding section focusses on some of the means, mechanisms, and lessons learned that can be used to enjoy a relative level of success in the near distant future in our ever knowledge-intensive and centric industry.

- ***Knowledge use*** : The efficient storage, retrieval and reuse of information and knowledge, facilitating teamwork, remains a hot research and development topic. Rightly so, since knowledge and experience is a most valuable asset for organisations. Knowledge of what ICT can and cannot achieve is part of that, but social interaction in the workplace - people mixing and talking together – remains the essential ingredient.

- ***Construction evolution*** : The technology future of ICT can hardly be imagined let alone. What is certain is that all of the above will impact construction in unprecedented ways. The critical mass is aggregating; boundaries between industry sectors are blurring; business rules are changing. Construction ICT is just one tool supporting change but one with an enormous potential for process innovation.
- ***Impacts and benefits*** : The organisationally fragmented construction industry, with its inherent risks and uncertainties, has led clients and contractors to look actively for ways of improving overall quality and performance. One development of the last decade has been the recognition that projects should be more collaborative, not just cooperative – an integrated team with a single project focus not just interacting teams, from a "bag" of independent sub-contracts.
- ***Time telecope (Vision)*** : Technology is not the starting point. Look at the process; look for inefficiency and waste; then look for solutions.

## 4.2 Summaries of ICCI book selected chapters

### 4.2.1 An industry perspective on work

*As mentioned, this section refers to a case study of the performance of a fictitious, but realistic, project through the eyes of the main contractor.*

Ken leaned back in his chair, feet on desk and a report on his lap. 'Close-out Report for Chepton Project – Key Lessons' stretched across the document's cover. Chepton was a large town-centre retail development and Ken's company was the main contractor. If only the word 'Learnt' could be added to the end of the title, he thought. The Executive Summary presented a positive picture but Ken, as Director responsible, knew that Chepton had had its problems. Reading on, he also noted down his own thoughts.

Design Team / Construction Team Integration – Chepton was a prestige project with well known architects and consultants involved in concept development, detailed design and coordination, and numerous specialist suppliers. A 3-D visualisation had been commissioned to aid discussion within the design team and with the client. It had identified at an early stage several "buildability" issues to be solved. But Ken knew that you can't build from visualisations, no matter how good they appear, and that what is required is well coordinated drawings, specifications, schedules and lists – with good team communication. There had been some expensive mistakes (in lost time and money) that mainly arose from information changed in one document not being changed in others, leading to problems of spatial coordination of the complex building services that only discovered during construction.

*Note: we all need the detail (designers, constructors, users & maintainers). The problem is we need it in different sets, and formats suited to particular uses. Can this be done?*

The Project Team – Good team working had been a focus at Chepton from the start, with the client even hosting some early team building workshops. Ken's company organised monthly coordination meetings around the master plan - welcomed by some suppliers but regarded as time consuming by others. Despite efforts, decisions did not always reach the workforce, especially those only intermittently present on site, such as specialist sub-contractors.

*Note: we need better and easier ways for remote groups to "understand" projects from different perspectives. Progress of different trades; the future work plan; the up-to-date master plan to comply with. With effective ways for the workforce to see this too!*

Planning and Reporting – Key Date Planning for "high profile", "client critical" target dates, gained more commitment than mundane (yet important) intermediate goals. The project had taken longer to begin than the client wished, partly due to late design changes, with the

construction program shortened – and different trades sometimes "falling over one another". Some felt that alternative program strategies might have been possible and would like to have done their own "what-ifs", but software incompatibility hindered this from being done easily.

*Note: we must build on this in new projects, providing a sharable time and workflow "model" showing key dates tied into what they mean to the client.*

Change – There had been more changes than usual, requiring rework in design and on-site. From the outset the client had a clear vision, but other "non-contracted" parties including the eventual retail occupants, adjacent property owners and an environmental agency had to be satisfied. Retailers wanted late modifications to suit themselves and a late environmental decisions had delayed the overall work program. Hidden underground services were uncovered needing diversion, better knowledge of which could have saved delay and costly rescheduling. Only one utility company held data on a Geographical Information System. Drawings were produced using CAD and could be received at site by broadband, but the contract specified that information had to be by paper copies.

*Note: we must ensure we keep on top of change requests, being flexible but always formally logging them. Beneficial having drawings electronically in our Document Management System.*

Computer Systems – The project was not innovative (using familiar materials and methods), but Ken's company had used 3D visualisation to test the construction sequence. The visualisation was newly created because it was not possible to use the designers' CAD information directly due to incompatible systems. Some felt that ICT facilities had not been exploited fully because of incompatibilities, security concerns and training. But there were exceptions, and excellent work had been done by two young graduates that allowed retail occupants to report problems over the Internet. The site team felt that having an ICT strategy at the outset would have been beneficial, with "expert" facilitators from within the company to stimulate ICT potential and to advise on effective training.

*Note: look at more exploitation of ICT, including exchanging information with others (not just drawings) Surely ICT could improve supply chain. Look into requirements for model ICT Contracts. PS. Nominate graduates for an Innovation Prize.*

Ken buzzed his secretary. "I'd like a meeting next week with a few others to discuss some ideas I have. Could you check my diary? By the way, do you know how far they have got implementing the diary management system?"

*Note (to myself): we must always remember that all-round competence and professionalism matter. It is people, knowledge and systems that help win contracts and complete them success.*

### 4.2.2 Knowledge use

Project members and teams are constantly in pursuit of the right information at the right time but the practical reality is that it rarely happens! Either it is buried in paper files or clogged-up in an IT system. Worse still, it may never have been recorded. Too often when a project ends, so too do the memories of lessons learned and experiences gained. Today, we can be simply overwhelmed with information and too busy to share what we know. Experience and the knowledge from it is the capital worth of individuals and organisations and needs to be handled properly so as not to "reinvent the wheel" on each new project and repeating past mistakes.

In the beginning, knowledge is unstructured and scattered (amongst people and systems). Experience will often be in the form of anecdotes in the heads of individuals (tacit knowledge), but it can become partially structured as, for example, rules of thumb. More structure and meaning is added when it is made available in a tangible form to others. It becomes fully structured (or explicit) when it can be made into a set of formalised rules for use by others.

Knowledge tends to be best handled through communities, not just in libraries or document management systems. Knowledge distribution is first a social action and next a technical (enabling) process. Two forms of knowledge sharing communities exist: digital and social. In *digital communities* the knowledge is stored and shared through digital media. Today the Internet facilitates online discussions, access to remote documents and, even, chat. In most cases, knowledge is stored in some structured form for ease of identification and retrieval (for example, according to a topic hierarchy). *Social communities* have always been the preferred way to share knowledge in our industry, like-minded people come together to share their experiences: stories are recalled when people face a similar problem. There is no best recipe or single tool for knowledge sharing. It depends on the organisation and the people. Expect some significant developments in this area for all industries.

### 4.2.3 Impacts and benefits

The organisationally fragmented construction industry, with its inherent risks and uncertainties, has led clients and contractors to look for ways to improve overall quality and performance. There has been a culture drive for projects to be more collaborative - an integrated team with a single project focus, i.e. the “virtual” team. ICT is assisting construction disciplines to become more open and trusting of each other by sharing project information electronically. But realisation of the benefits of ICT as opposed to its cost has been slow compared to other industries, primarily because the culture of the industry is one of cost avoidance. However, declining product quality, fuelled in some countries by skill shortages, has prompted consideration of ways to better foster skills and to invest to raise productivity.

Cross-discipline communication between the many interests is often problematic and a major contributory factor to poor project performance. Technology, telephone, e-mail, the Internet, video links, electronic whiteboards, virtual reality simulations, electronic catalogues and much, much more have shrunk time and distance. A team half way round the world can be as close as the one on the next floor. Interpersonal communications have been revolutionised – at a cost affordable by almost all organisations, and even individuals.

Crucial to any construction project is the passing of project information between parties. Historically, drawings and specifications have been the means of formal inter-organisational communication of project information. The first step to better coordinated information – paper and electronic – is to manage it amongst the major players in a project to support integrated teams. Integrated Information Management Systems are a means to order information (e.g. electronic documents) for ready access and retrieval anywhere, anytime, by anybody. Integrated teams are thereby supported.

The next step is fully integrated data, combining the data and information content of drawings (size, relationship, position and composition of construction elements), specifications (material, performance, manufacture), schedules (time, resource, cost) and reports (technical, management, financial, etc). In other words, information aggregated around an object not attached to its representation. This has been a major goal in many industries, including construction, involving bodies like the International Organisation for Standardisation (ISO), European CEN and the IAI. The EC strongly promotes open standards and the Open Source Software Foundation (OSSF) is nurturing the concept of "free" software. Why is openness important? Data is now tied to proprietary software, forcing use of that software. Exploiting data for other purposes in other applications needs high technical expertise. Openness offers choice and flexibility. So ontology (the meaning of terms), product models (attributes/ properties of objects and their relationships – from the whole facility to individual parts, like a door) and new “model based” design software are primary foci.

The third step is to enable interchange of data and knowledge between different information systems. This requires software interoperability – so that the architect's design can pass to the structural and building services engineers for reuse in their designs, in specifying system components and in procurement.

The target (the "eConstruction" future) is: . . . *Model-based and object-oriented . . . supporting company/market knowledge and project information management & sharing . . .via Open Standards . . .over the Semantic Web . . .with (legally backed) trust.*

### 4.2.4 Vision : questions and answers

Some exciting future ideas can be "dreamed" of but how realistic might they be? It depends very much on your viewpoint. Technologically a lot is practicable - the hardware, software, standards, etc. exist or are being developed.. But a practitioner view might be that such ideas are too futuristic and the value now perceived questionable.

- Quite visionary things are possible, but not everything that can be done should be done!
- Active involvement of industry is essential to specify the "really useful" work scenarios.

Question : Do we have to be concerned about all the different strands of technology?

*Answer : There is a lot of "generic" hardware and services. Our concern must be the technology that we must provide. We must take responsibility for our own needs and affairs.*

Question : Is it simply not practicable for industry companies to develop software themselves?

*Answer : Like any business, others provide services that we integrate into our way of working. The service providers are software developers and vendors. They need market "pull" and stimulating that is part of industry responsibility. Software houses respond to industry leads, but can be proactive in "lighting the way".*

Question : Is there one technology I should attend to?

*Answer : Model Based Technology. Underlying most cameos is intelligence – objects knowing a lot about themselves and how they relate one to another. This technology integrates information and facilitates collaboration.*

Question : Is this technology unique to construction?

*Answer : No. It is common technology in advanced industries and business sectors. Unique are the internationally agreed objects and properties with which we deal. Think objectively!*

Question : What can it do?

*Answer : It depends on the information entered and the processes applied to it: concept development; architectural, structural and building services design; cost estimation; construction planning; facility management; safety and environmental assessment etc. Different specialists/applications pool information though detail may be held privately in different places.*

Question : What can I see?

*Answer : Arguably the most impressive and easiest examples to follow are those that manipulate models in 3D. Those that reveal deeper potential compute complex flows (forces, heat, people etc) and "size" the visible components.*

Question : Where can they be seen and tried?

*Answer : Vendors willing to demonstrate and allow"hands-on" session are presently being listed to be available at the ICCI and IAI web-sites. Technology is not the starting point. Look at process; look for inefficiency and waste; then look for solutions.*

## 5 Conclusion

ICCI has provided an excellent opportunity for RTD projects to cooperate in their work with the aims of better informing industry organisations of the breadth of work being undertaken, offering input to the EC research frameworks and informing the wider European research community. One huge benefit has been the cooperation fostered amongst the teams (numbering more than 50 partners in all). ICCI took upon itself responsibility for assisting one of the essentials for ICT use, the establishment of Standards. The project maintained dialogue with the International Alliance for Interoperability (IAI) through European national groups in developing standards for semantic information exchange. Work from ICCI has directly contributed to the scoping of IAI activities and has supplied public deliverables into the work of IAI. ICCI has also successfully pursued the initiative of a CEN rolling-Workshop on e-Construction: before summer 2004, the Workshop will produce a set of Common Workshop Agreements to establish by consensus a European view on formal standards to support eBusiness in construction.

ICCI can be seen as the first concerted initiative in the fields of Construction ICT R&D, whose primary objective was to harmonise results from past and ongoing research and development projects, whilst providing useful background information in the form of industry and R&D recommendations that will (a) help promote the Construction industry, (b) improve general practices and adoption of ICT, and (c) provide useful sources of information to funding bodies and governmental organisations to shape and define future agenda and strategies for the sector.

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