Building, a Better Future

Constructed by People with ICT

ICCI

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- Acquire free demonstration versions of commercial software
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Just enter http://icci.vtt.fi and go to The Book
or http://www.iai-international.org/ and go to ICCI The Book

This document does not describe the ICCI project. However, the scope of ICCI is presented on the back cover, with the web-site address where details of the work, results and deliverables of ICCI may be found. The ICCI partnership expresses sincere thanks to the European Commission for funding the project under the Information Society Technologies programme.

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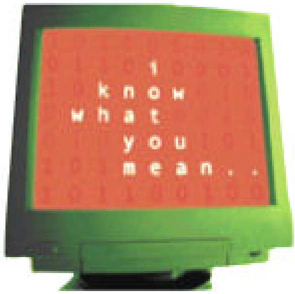
Full acknowledgements are shown on inside back cover.

Building . . . a Better Future

WYSIWYG -what you see is what you get - is a familiar computing acronym. What is on the screen will be faithfully reproduced on paper when it is printed. It is a phrase intended to inspire end-user confidence. No hidden surprises!

WYSIWYG is not, however, a concept that would seem to translate readily to the construction industry. The construction client does not "buy" a tangible product but "buys into" a dynamic process from which, over time, the product evolves. So, no chance for him to see before he buys!

Well, *apparently* no chance. The good news is that over the past decade major research and development strides have been made in the ability for the design and construction teams, and the client, to collaborate in product development and to test the product before construction starts. WYSIWYG for construction, no less! How? - by building the product electronically in the computer before building it on site – modelled in virtual reality. Able not only to visualise and walk-through the product, but to *experience* it – to assess, in advance, the working performance of lighting, internal climate, escape routes, construction methods and "final consumer" use.



In one important respect virtual is *better* than real – the ability to make changes and test alternative solutions at the level of the product or any of its component systems or parts. It is this that heralds the prospect for a better future for building and construction. Able to prototype electronically with greater assurance and for the model itself to be part of the team collaboration process. "Talk with your building" might well become a new building catchphrase and a whole new experience!

We hope that this booklet will reveal the underlying concepts and work that are contributing to making WYSIWYG a reality for construction. Some parts are quite technical, with more than a fair share of acronyms, but please try to get a flavour of what is being done to enable commercial development of new Information and Communication Technology systems that will integrate the work of distributed teams, allow fast and accurate communication, facilitate knowledge sharing and generally support the historically versatile (some would say chaotic!) construction industry.

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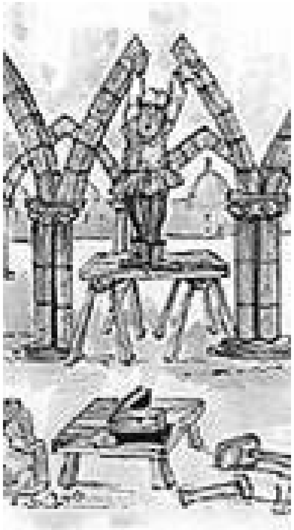
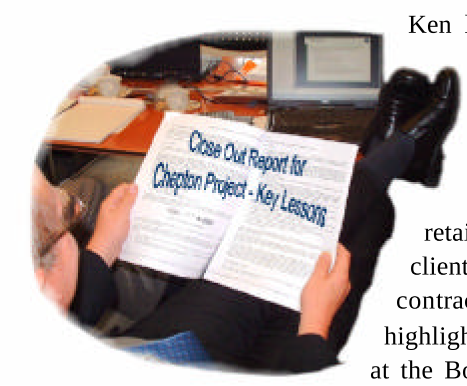


An Industry Perspective on Work

The focus of this booklet is 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. This chapter is a case study of the performance of a fictitious, but realistic, project through the eyes of the main contractor.

1. Final Account



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 for an experienced client and Ken’s company was the main contractor. The following week he would highlight key points to his fellow directors at the Board Meeting. He approached the document with a sense of déjà-vu. ‘Key Lessons’ usually followed very familiar patterns.

If only the word ‘Learnt’ could be added to the end of the title. He knew that some people would take lessons to heart but others would shrug their shoulders, move to new projects and continue to propagate what Ken referred to as i^3 – institutionalised industry inefficiency – with client, designers, suppliers and contractors mobilising “just-about-in-time” for new projects.

Nobody was without some blame; not the client nor he had to admit, his own company. People invariably focussed on their fee-earning contributions, not on the global project interest.

Taking Note

People are the biggest critical success factor in any project.

The Executive Summary presented a positive picture with the project completed more or less to time and budget with a satisfied client. But Ken, as Director responsible, knew that Chepton had had its problems. Reading on, he also noted down his own thoughts.

<u>Design Team/ Construction Team Integration</u> – Chepton was a prestige project with large, well known architects and consultants involved in concept development, detailed design and coordination, but also numerous specialist suppliers. Encouraged by the client, a 3-D visualisation of the scheme had been commissioned by the lead architect to aid discussion amongst the design team and the client. It had usefully portrayed the look and feel of the scheme to the construction team, and to sub-contractors as they came on board. It had allowed some “buildability” issues to be solved at an early stage and had helped to gain community planning approval.

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 communication amongst the team. Here the project had struggled at times – there had been some costly mistakes (in terms of time and money). These mainly arose from information changed in one document not being reflected in changes in others, leading to serious coordination problems in the complex building services only uncovered during construction.

It was also apparent during construction and commissioning that there were insufficient records of design decisions and product performance specifications – the ‘why’s’ (important when products had to be substituted).

`NB. 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 good efforts, strategic messages did not always reach the workforce or those only intermittently present on site, such as specialist sub-contractors. Communication and co-operation between different disciplines had sometimes been poor, even inside individual companies.

NB. 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 appropriate ways for the workforce to see this too!

Planning and Reporting – Key Date Planning contributed to success. Clear, high profile, "client critical" target dates, gained commitment over more mundane (yet important) intermediate goals. The project had taken longer to begin than the client wished, partly due to late design changes, with the result that the construction programme was shortened - with different trades sometimes "falling over one another". Some felt that alternative programme strategies might have been possible and would like to have done their own "what-ifs", but incompatible software prevented this being done easily.

NB. 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.

Control and Management – Client and main contractor reviewed work packages regularly, linking progress to budgets, cash forecasts and time schedules. Weekly work package meetings took place on site between the responsible managers and suppliers, with daily meetings at the work supervisor/lead operative level. All well and good, and many problems were avoided or sorted, but changes of plan were not always properly investigated for downstream impact nor the reasons recorded, so that non-performers were not always held to account.

Quality Control and progress of off-site work had presented problems, needing an external inspector to be employed to check physically that manufacturers' promises were met.

Completion of works had been an issue, with areas needing to be occupied at set dates for the client to earn rental income. There had been misunderstandings and some areas were occupied before building services had been fully commissioned – occupied but not handed-over!

It was reported that quality had worried some in the design team, concerned that there might be inadequate understanding by the construction team of how to achieve the required quality. Quality standards could have been set earlier with perhaps full-sized prototypes. Defect lists were inflexible, ordered by work package and not work area. The ability to select items according to different criteria and present in different ways would have been useful.

NB. Need to integrate information more effectively – drilling down for detail when needed. Able to do it anywhere, anytime. Flexibility is key requirement.

Change – There had been more changes than usual making it difficult for people to keep up, with the inevitable rework in design and on-site. From the outset the client seemed to have a clear vision, but there were other "non-contracted" parties around the project including the eventual retail occupants, adjacent property owners and an environmental agency. Retailers wanted modifications to suit themselves, placing possible limitations on future use of space. And late environmental decisions had delayed the overall work programme.

Build a first class team and they will play for a successful result . . . in construction as well as "the golden game"

Uncharted underground services were uncovered needing diversion. Better knowledge of the hidden infrastructure could have saved considerable delay and costly rescheduling. Only one utility company held data on a Geographical Information System.

There had been gradual change of requirements, with considerable re-design done beyond that shown on the original tender drawings. Better division of work between outline and detail design was required and better control of change. Drawings were produced using CAD and could be received at site by broadband connection, but the contract specified that information had to be by paper copies.

NB. Must ensure we keep on top of change requests, being flexible but always formally logging them. Beneficial surely to have drawings electronically for our Document Management System.

Computer Systems – The project was not particularly innovative (using familiar materials and methods), but Ken's company had used 3D visualisation to prove the effectiveness of the construction sequence. The visualisation, although simplified, had to be newly created because it was not possible to use the designers' CAD information directly (although offered) because of incompatibility between systems.

Some felt that whilst good ICT facilities had been provided on site, they had not been exploited fully because of incompatibilities, security concerns and training. But there were exceptions, and excellent work had been done by two recent graduates that allowed retail occupants to report problems over the Internet, for downloading to a simple spreadsheet database.

The belief of some in Ken's site team was that a clear ICT strategy at the outset would have been beneficial, with the use of "expert" facilitators from within the company to promote ICT potential and to advise on effective training.

NB. 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.

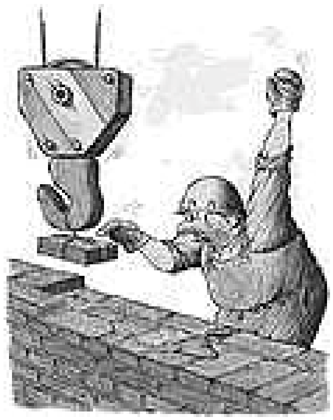
Taking Action

Ken finished his third coffee and buzzed his secretary in the outer office. “I’d like to convene a meeting on Tuesday next week. It will involve a few people from other departments to discuss some thoughts I have. Could you check my diary? Oh, and by the way, do you know how far they have got implementing the diary management system?”

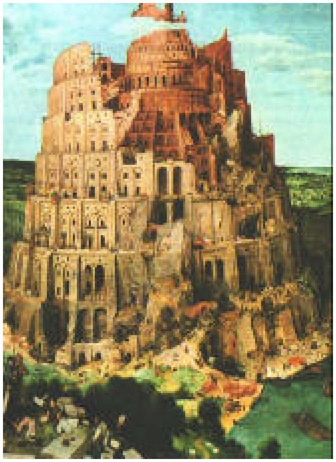
`NB to myself. We must always remember that all-round competence and professionalism matter. It is our people, knowledge and systems that help us win contracts and complete them successfully!`

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.



2. Communication



Giuseppe is a builder. A good one; perhaps the best in Italy. It is 1389 and he is spending his fourth winter in windy Turin. On good days he can see the snow capped Western Alps. On rainy or snowy days, and most are such, his back “kills” him. He’d like to move on – he expects a commission in much warmer Naples but he cannot leave; not until the dome of the cathedral is finished. Only he knows what it should be like and unless he is on site, others “mess up”. He cannot be in two places at once! But the wine is good ...

The Old Testament provides an early example of the role of communication in construction:

> Genesis 11: 4 *Then they said, “Come, let’s build ourselves a city and a tower that reaches heaven; let’s make ourselves famous, so that we will not be scattered here and there across the Earth.”*
>
> Genesis 11:6-8 *God took one look and said, “One people, one language; why, this is only a first step. No telling what they’ll come up with next – they’ll stop at nothing! Come, we’ll go down and garble their speech so that they won’t understand each other.” And they had to quit building the city. That’s how it came to be called Babel, because God turned their language into “babble”.* [© The Message]

Building of the most ambitious construction project of the time - the tower of Babel - halted when the builders ceased speaking the same language. Absence of communication prevented co-ordination, so work stopped!

However, a succession of communication revolutions over several millennia has allowed construction to progress from a localised craft origin to a globally distributed, virtual enterprise industry. We are now in another huge technology-based process and communication revolution that is impacting the business capabilities and prospects of companies (far quicker than earlier revolutions, but no less strategic). It is a revolution that companies cannot ignore. It is technology-based, but fundamentally it is a new way of thinking and working that requires careful attention.

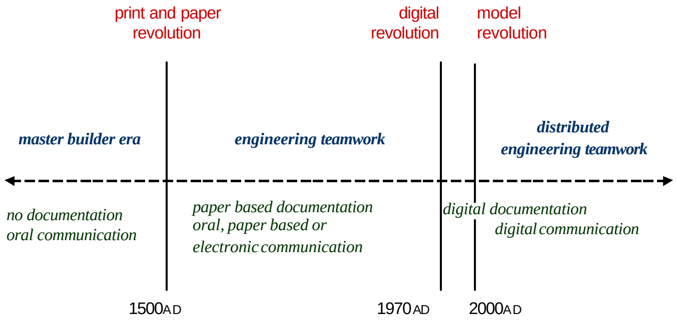
Communication Revolutions

The history of science and technology reveals several key communication revolutions:

the writing revolution, using symbols to represent things or ideas, dates from before 3000BC. Papyrus, a portable medium, began to bridge space and time, but **the paper and print revolution** of the $15^{th}/16^{th}$ centuries, founded on the invention of cheap paper and the printing process, first established information broadcasting of text and illustrations. And scaled drawing and projections (relating different views) provided new technical communication. Paper remains the primary information medium and the construction sector has not yet adapted to the "new digital paradigm". Business tools *have* changed, but *not* our professional tools - that are the most important.

the electronic revolution of the late 19^{th} century “de-materialised” communication media and massively increased the speed of communication. It took another 100 years before not only sounds (telephony) and characters (telegraphy) could be sent electronically, but drawings (facsimile, fax) so central to engineering.

the digital revolution began democratising the electronic media in a similar way to the press with printed news and information. Of greater importance to technical industries like construction is the **current model revolution**. Together they allow the rapid transfer of any kind of information and is the basis for the so-called information economy, where information is the money-making, traded commodity.



Distributed engineering teamwork

Communication is fundamental to all the issues discussed in this book. Communication theory defines several characteristics:

Session topology: the range of communication (from one-to-one to many-to-many)

Identity: awareness or anonymity of the communicators

Actor type: the type of communicator - human, software, hardware

Timeliness: time lag in communication – from instantaneous (e.g. telephone) to several weeks (e.g. monthly updates)

Location: proximity of communicators

Mobility: whether communicators are at fixed locations (e.g. office/site based) or are mobile (i.e. moving between different places)

Format and encoding: the communication medium and how information is packaged

Carrier: the communication channel (e.g. material – paper & post - or electronic)

Today, many combinations of these characteristics are supported with considerable impact on the mobile and highly flexible construction industry.

In an ideal world, construction communication would be restricted to moving only formal documents and detailed structured information between parties. However, such ideal communication would be expensive in human and financial resources, so the industry has developed the art of creating and exchanging less-than-perfect documentation, with any shortcomings being understood by recipients from the context, or resolved by personal discussion i.e. not everything is explicit.

Land lines and GSM phones, IP telephony, video links and application sharing help make remote person-to-person communication quite as productive as face-to-face contact. 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.*

3. Process Management

"One thing that is constant is change" – certainly true of construction projects. Each project presents a different set of business, financial, technical, production, location and people problems that must be managed over time.

The big challenge is that the construction project lifecycle is dynamic, not static:

There is a **process metamorphosis** from the management of paper/electronic design into the management of physical construction.

The **team changes** from client initiated, to design led, to production driven, to facility operated. Particularly in the production stage, sub-contractors and suppliers change frequently as their turns come around – groundwork, steelwork, roofing, services, etc.

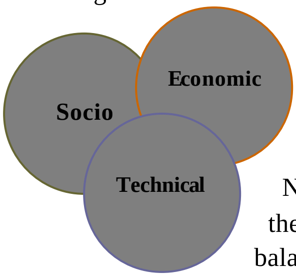
The **workplace changes** from open air to open space, to open floor to empty room.

The **tools change** from those for business strategy and requirements capture, to analysis and design, costing and scheduling, digging, lifting, drilling, monitoring and maintaining.

Processes

Process management is multi-faceted, involving three underlying process streams:

- *Material*,
- *Information* and
- *Management*



Material Processes are related to human and machine tasks that produce physical objects – activities like making, transforming, moving, storing, measuring and assembling. This is the realm of construction work, component manufacture and supply logistics. Flows of material move between stations in a production line or from seller to buyer.

Information Processes are concerned with creating, transforming, moving, storing, calculating and relating information needed to carry out the material processes. For every "real" system (spatial, structural, transportation, safety etc.) there is a corresponding "information" system. This is the realm of Information and Communication Technology (ICT) tools. As with material processes, information may move locally within one company or discipline or be distributed to different companies and disciplines to be reused and transformed.

Management Processes are often overlooked. They track the actions, resources, finances, time, supply chains and permissions that regulate and control projects. They are a kind of meta-data for material and information processes i.e. data about data that gives a high-level picture of progress, performance and profitability. This is the domain of company management, client reporting and contractual agreements.

Notably, in the construction industry there is a socio-technical-economic balance, placing people at the heart of any process along with how it is undertaken technically and at what cost and benefit.

Workflow

The concept of Workflow is defined by the Workflow Management Coalition (WfMC) as "the automation of a business process, in whole or in part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules". Some transfers are intra-organisational, but the more challenging ones are inter-organisational.

Workflows may be ad-hoc, administrative or production related:

Production workflows are highly structured and deterministic – candidates for automation by machinery and calculation. *Administrative* workflows are repetitive and predictable with perhaps a small range of fully known outcomes and simple rules for coordination. They are candidates for computerisation and structured information processing but do not themselves add product value. *Ad-hoc* workflows are processes with no set patterns for movements of materials or information between people (more reacting to events).

Time to think and plan is required. Thinking before doing is personally very costly but cheaper by far financially and in wasted effort.

The construction lifecycle involves a mixture of all three kinds of workflow but with a high proportion of the ad-hoc. There is an implicit underlying process in the scheduling of projects, but short term activities are decided as the facility evolves from a client business need to a finished structure. Projects are individually unique, with considerable problem analysis and solution exploration required.

Methods

Construction projects are characterised as "virtual enterprises". The integration of the overall process requires connecting, where possible, workflows in different organisations.

Integration of inter-organisational workflows currently rely on predefined public interfaces for communication, and data exchange between collaborating ICT systems. The predefined public interfaces, such as XML schemas and Web services, usually focus on transactional data between collaborating organisations. This is satisfactory for deterministic or repetitive processes (administrative or material) with fixed scopes and contents, but for ad-hoc and complex production workflows public interfaces are too inflexible.

"e-Business" needs to support virtual teams having fuzzy organisational boundaries. This means developing the ability not only to exchange *data* between organisations but also part of the *intra-organisational workflows* of each enterprise. The sharing of process models with client-controlled private and public portions and the human interfaces to these portions is not possible through current Web-hosted services, but has been proposed for next generation Web hosting services.

Challenge

The workflow to undertake effective cross-border process management in virtual teams in construction projects presents not only a considerable technical challenge but an *even greater* cultural challenge. This will take time, so timely preparation essential.

4. eCommerce

These days site construction is mainly an assembly process and, of course, what is assembled has first to be procured. A third or more of the cost of a building relates to procured off-site materials, systems and components (everything from reinforcing bars to door handles) – thousands of items that are specified, selected, ordered and delivered within the contractor, sub-contractor, supplier and manufacturer procurement chain. Paper catalogues, telephone, fax and "snail" mail were the tools of the last century but email has displaced fax and now the browsing of electronic web catalogues is beginning to impact product discovery. Furthermore, applications like online airline e-booking and e-ticketing have provided powerful, user-friendly examples of eCommerce for the construction industry to follow.

Electronic Commerce (eCommerce) refers to all computer supported trading/procurement between (potential) buyers and sellers in the supply-chain.

There are two main phases

Shopping– enquiry and product selection with information requested from suppliers and returned to the enquirer

Fulfilment - when specified goods or services are committed to, provided and ultimately paid for.

Shopping (product or service discovery) is often undertaken through "web portals"- gateways to multimedia product information (text, pictures, tables etc) provided by subscribing suppliers. Enquiries may be broad-based with only a few defining product characteristics ("I want something like this") or more specific ("I need a product of this precise type"). Importantly, the enquirer is in control.

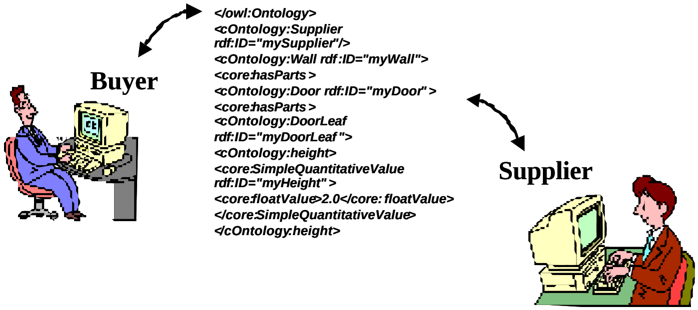
Fulfilment deals with the buying of a particular item by Electronic Data Interchange (EDI) type bilateral transactions – the key literally being a unique product reference i.e. the supplier's catalogue number or a formal Electronic Article Number (EAN). Primarily, the transactions comprise data that specify the who, what, when, where and (sometimes) why of the product or service being procured. There will normally be at least two exchanges, one to place an order and one to acknowledge it, but there may be many more covering delivery notification, invoicing, payment etc, some of which may involve third parties like banks. The aim is to automate processes as far as possible and to reduce the cost of "non value adding" business effort. Control is shared between customer and supplier.

There are a number of significant advances being worked on to support Construction eCommerce. First, the technology is proven. It is in day to day use in other business sectors. Why not construction?

In the last decade, the cost of bank transfers has reduced to 1/100th for Internet transactions. In many key practices in construction, there has been little change.

Two things are required:

In the ***shopping phase*** the requirement is for global agreement (all parts of the industry, worldwide) on a **standard way to comprehensively and uniquely describe goods and services** so that different suppliers' catalogue items are directly comparable. Thus, *agreeing meta-schemas ("how do I describe products in general") and construction product/service ontologies ("what products with what properties are relevant") are among the most important issues to be resolved*. The good news is that work is underway to bring about convergence of various overlapping solutions to this need (IAI IFC, eConstruct bcXML, ISO 12006-3 and W3C OWL).



In the ***fulfilment phase***, whilst the principles of EDI established in the 1980s hold true, a far more **powerful vehicle for transactional exchanges has fast gained ground and is in wide business use – namely, ebXML** (electronic business XML). This was initiated by UN/EDIFACT and OASIS, and promoted in Europe by CEN/ISSS eBES. The extension of ebXML to the construction sector is active in several European countries.

Both standards and technology are needed to meet the requirements of the procurement cycle – allowing data driven specifications from the shopping phase to be seamlessly communicated in the process driven transactions of fulfilment. Enabling specifications and transactions to "shake hands" through appropriate levels of compatible semantics ("agreed *definitions* of information content") will facilitate their integration in intelligent business objects and support the kind of flexible communication the construction industry is used to.

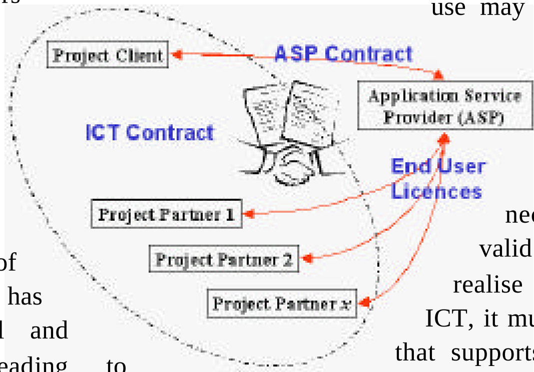
The belief is that business support technology like Ontology Web Language and Web Services that are fast maturing under the auspices of the World Wide Web Consortium, will make this scenario happen.

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. Moreover, electronic transactions will provide the data to profile customers, anticipating their requirements and proactively marketing products to them.

5. Legal Issues

Collaboration in Construction

Increasingly, the digital communications revolution has enabled project stakeholders to use collaborative environments as a means to manage project communications. Collaborative environments employed by construction organisations include: extranets, intranets, and groupware programs. Wider use of such technologies has led to ICT outsourcing to "Application Service Providers" (ASPs) which set up and manage services on behalf of their clients to provide facilities and functionality for other project participants.



However, 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.

ICT Legal and contractual barriers

European studies have shown that there is little reference to legally valid use of ICT within construction industry contracts. Where ICT clauses are included they are typically limited to specifying the types of software and file exchange formats to be used on a project, or broad and imprecise statements such as "data has to be valid, secure, well organised and properly managed". The underlying message is that still the only method for achieving legal admissibility has remained the use of a hand-written signature on a paper hardcopy.

To encourage the application of ICT, the Contract could be amended to identify and to define communications to be 'in electronic format' instead of 'in writing'. Official documents (correspondence, drawings, specifications, data) are still formally submitted solely on paper. The use of ICT speeds up the transmission process, but often without legal validity. Although legislation to support technology use may exist, it has not been adopted by the industry within its normal contractual practices, and so the use of ICT is not necessarily contractually valid in today's practice. To realise fully the benefits of ICT, it must be applied in a way that supports the project and the transactions and, moreover, *in a legally admissible manner*.

ICT Law ranges across many legal aspects, from trade law to intellectual property rights, from data protection to criminal law. An emerging issue, applicable to the construction domain is the use of "intelligent agents", which may, for example, search intelligently in electronic catalogues for the most appropriate fire door to fulfil the design. Another use may be in contract negotiation and execution, with "agents" assigned parameters, criteria and authorisation to communicate with the "agents" of other contractual parties - carrying out transactions on behalf of the agent's owner. But the performance of such agents' actions still need a coherent legal framework.

Solutions for Trust and Confidence

To permit Trust and Confidence in electronic transactions from different stakeholders in the construction project, transactions must be both *secure* and *legally valid*.

Transaction security is achieved through various complementary solutions. A user exchanging private information across the Internet via a web server on the Internet, can be *confident* that information is being sent to the right place thanks to a valid *Secure Server Certificate* issued to the manager of a web server by a *Certification Authority*.

Electronic signatures allow a recipient of each piece of information to know when the information arrived, who sent it, and whether the information was changed since it was first sent. As eCommerce grows, the role of *digital notary* services are becoming important in combating potential exposure to errors, tampering and denials in electronic transactions on open networks.

A digital (or electronic) notary proves who has made an electronic transaction, with whom, and when it was made. Digital notary *services* can, for example, validate the existence of a particular electronic document, such as a contract, at a given point in time. This is achieved by receiving the document with the author's electronic signature attached, verifying the signature, and returning a copy of the document, complete with the notary service's digital signature, and a guaranteed date and time that verification took place. A *digital postmark* will be authoritative in cases of conflicting claims regarding, for example, a contract.

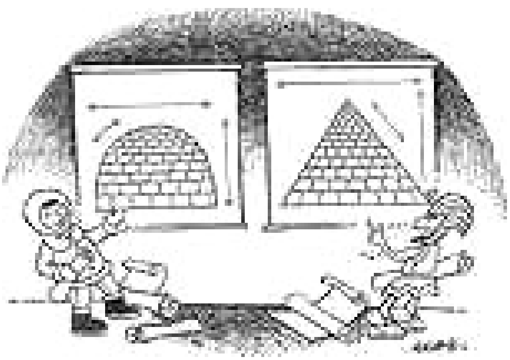
Despite the popularity of using ASPs to provide ICT services to projects, again there is currently *no legal framework* to cover it. Creating a suitable framework may be simple for a lawyer, but for a project manager in construction it will be beyond his experience.

To this end, a suite of prototype tools has been developed (by the e-LEGAL project) that enable contracts to be formulated and negotiated online. Actors in a project can describe their desired ICT environment (infrastructure and applications), provide and map clauses to these requirements using a reference clause library, and negotiate and digitally sign the contract. Electronic transactions are thus achieved in a legally valid manner as part of a framework for ICT use in construction.

Many, if not most, of the perceived legal problems have been overcome technically and procedurally in other industries. In construction, it will take a little while to create confidence (based on understanding), but the benefits of smooth, legal information exchange will shine through.

Using and Managing Information

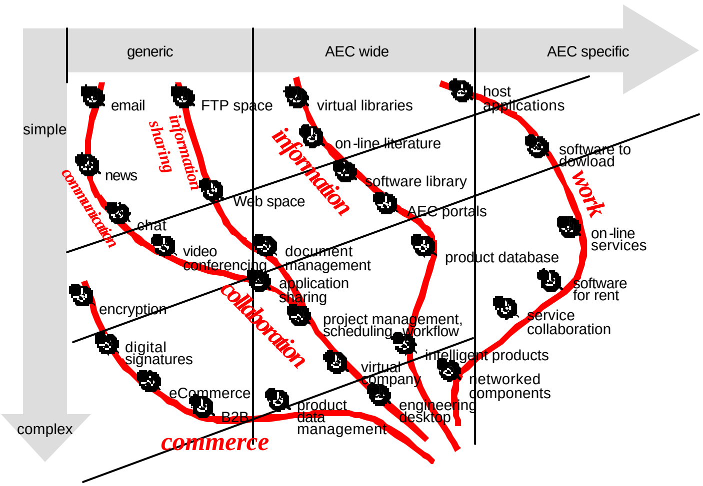
What are some of the technical developments that Information handling is based upon? Read on to learn something of the Web revolution and its future evolution; the integration of businesses, projects and software systems; the focus on "model-based" solutions; and the work to establish Standards for electronic communication of construction knowledge.



6. Spinning the Web

The Web was conceived in the late 1980s and proliferated in the early 1990s as a tool to promote scientific information exchange. It was quickly adopted to support almost any kind of human activity, but scientists and software engineers soon became the most enthusiastic users. These two professions have something in common with construction. They are both rather chaotic; they lack clearly defined business processes; they deal with mainly one-off products.

The Web was, and to a large extent still is, an umbrella that provides a unified access to several internet technologies including email, file transfer, discussion forums, access to databases and on-line computation. It is therefore not possible to discuss the Web and not the Internet in general. A couple of pages cannot do justice to the future potential of Web applications because most next generation software, if not Web-based, will be Web-aware.



Kinds of Web applications

The Figure opposite traces several communication technologies, positioning them according to their general complexity vertically, and according to their specialisation horizontally. However, the complexity is not measured objectively. Rather, two kinds of complexity are plotted onto the same axis. One is the speed of communication - more complex services are considered those that require a faster communication connection. The second complexity is computational, algorithmic and particularly data-structural, requiring greater investment of effort in software analysis and design. Horizontally, the generic services are to the left and more specialised engineering services to the right.

In the figure, four distinct groups of services emerge like paths and related pins have been connected with thick lines:

Information: On the information path technologies are identified that deal with retrieval of general information, aimed at several (anonymous) recipients for non-real time use.

Collaboration: To collaborate, people must be aware of what each other is doing and they must be able to communicate. This branch therefore divides into the sharing and communication of information.

Commerce. The commerce path connects technologies that deal with moving a particular kind of information – money - with documents that trigger its movement, such as bills, and invoices and special kinds of infrastructure (legal, encryption) that make transactions secure.

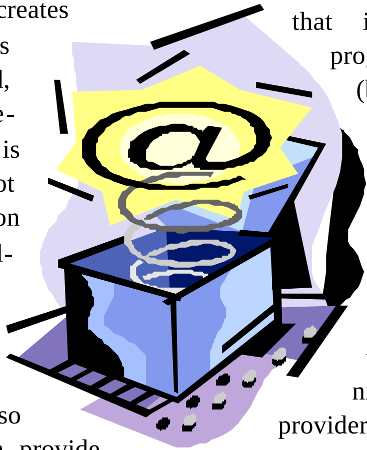
Work. The above kinds of activity are not those of core engineering, but are essentially overheads. Talking on the telephone, distributing CAD files and searching manufacturing databases are all parts of the design process - but none of these activities directly creates or augments design information. This is done when a drawing is changed, when structural elements are recalculated or a Gantt chart is evaluated. Tools that do this are not communication tools but production tools, and they are increasingly available on the Web.

As shown on the diagram, these technologies are merging. At least superficially they are made part of so called "portals" - web sites which provide access to a multitude of information, collaboration, commerce and work related services.

A web of services

The paradigm of a service seems to be the one that will shape the developments of the Web in the future. Today, engineers have most of the processing power on their desktops or notebook computers. They use the Internet to communicate and to find information - but applications that let them perform a computation or simulation on the Internet are currently rare and few are available commercially.

Applications that we use on PCs communicate with each other; most use complex internal Windows protocols such as OLE (Object Linking and Embedding) and DLL (Dynamic Link Library). If the applications move onto the Internet they need to collaborate using a simple neutral standard. This standard is XML. "Web services" are defined as services on the web that use XML to exchange data and are themselves described in XML so that that it is relatively easy for programmers to write interfaces (bridges) between them.

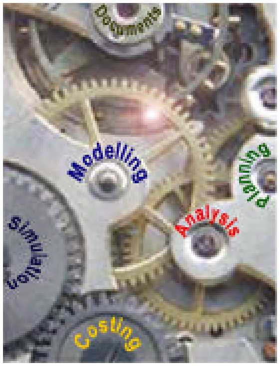


A likely scenario following from these developments is that engineering software will be available from the Web and paid for when used (like pay-as-you-go mobile telephones). Software companies of all sizes will be service providers relying on income from day to day use of their software rather than sales of software. Users will always have access to the very latest software versions.

As the capital cost of software reduces, the vital remaining capital cost will be that for *training* – understanding principles and learning how to use applications and interpret results. Remote learning and training, Frequently Asked Question and video linked expert support will assume far greater importance as value added service elements.

7. Integration

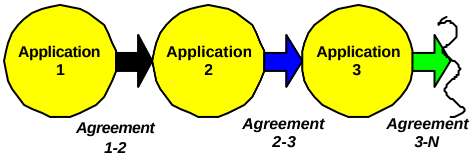
There are many different software applications in use, often even within a single organisation. Each application has a role and is developed for particular functional capabilities, but rarely the ability to communicate with other software applications. They act in much the same way that people in the construction industry do - alone!



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.

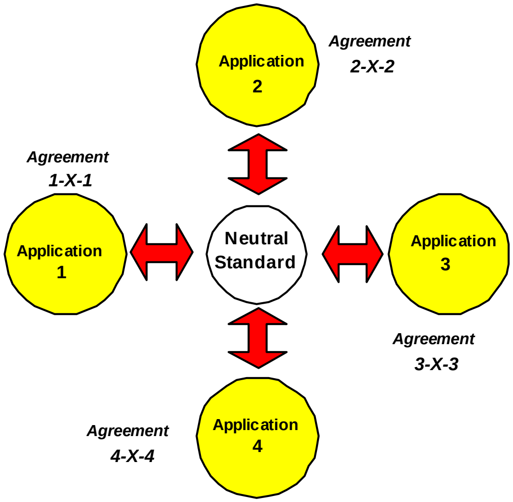
Approach to Integration

Integration may be achieved either with a serial or parallel configuration – rather like electrical components integrated in a circuit.



Serial integration means that two applications have reached agreement on a *common data structure* that can be used for communicating information. Information is passed by exchanging a stream of data (usually as a file).

When there is an agreement that allows many software applications to read/write a common data structure, then it is referred to as 'neutral'. This typifies a formal *data sharing standard*, with each software application needing only one interface to and from the standard to be able to communicate with many others.

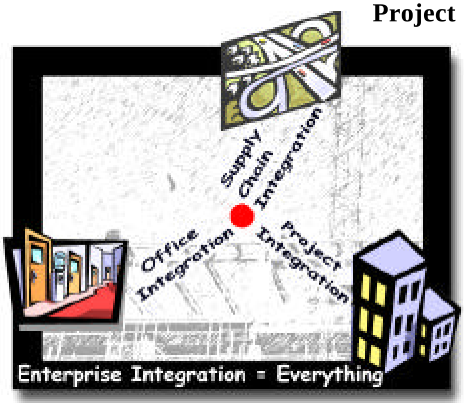


When a common data structure has been agreed, it can also be a specification for a database management system. Communication to and from such a system is achieved through a common application programming interface (API).

Using a database allows information to be both stored and communicated in a neutral form. Since every software application has access to the database whenever needed, this is regarded as parallel integration.

Purpose of Integration

Integration can relate to several purposes. **Office integration** unites applications that exist in the everyday office environment. Typical is the integration of databases with word processing and spreadsheet applications, accounting and management functions.



Project integration brings together applications that are used in project execution - applications such as CAD drawing, engineering analysis/ design, project scheduling, management etc. CAD communication is widely practised through standard exchange formats such as DXF. Integration between applications of different types is not common but it is evolving, having been the subject of research in the 1990's, then development by bodies like the International Alliance for Interoperability (IAI) and finally now at the point of maturity where many vendors are supporting or developing compliance with object communication (IFC). The major criticism of design team services is lack of co-ordination - *object model data and integration provides a demonstrably better solution*.

Lifecycle Integration is project integration further extended across operation, maintenance, refurbishment and demolition phases.

Supply chain integration collates information on the products and services purchased by an organisation from suppliers. It relies on stable, widely accepted standards for communication, particularly because the interaction between parties to communications is often short lived. Supply chain integration has been practised by organisations using EDI (electronic data interchange) standards for many years but electronic procurement approaches (eCommerce) are now becoming increasingly web based with the format for integration based on XML.

Enterprise integration may be regarded as the summation of all the above domains of integration. Office management, supply chain information and project data then fit together to communicate seamlessly using a collaborative data structure framework. Enterprise integration, a reality in some leading industry and business sectors that have long-term supply and sub-contracting relationships, is currently just a construction industry dream!

Data Environments

Parallel integration, utilising a common database, is beginning to occur on leading edge projects within the construction industry. A 'Project Extranet' data environment provides a secure, web-enabled, shared (but controlled) project information repository for project participants. Currently, most data environments work with a single proprietary data structure - for example a CAD data structure such as DWG (Autodesk) or DGN (Bentley Systems). This is sometimes referred to as the Single Data (type) Environment.

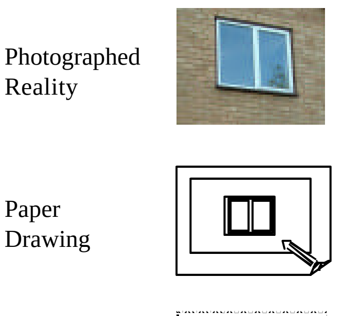
However, the real goal is that software applications should be able to communicate freely with one another, across any (and many) project extranets. This is sometimes referred to as the Common Data Environment.

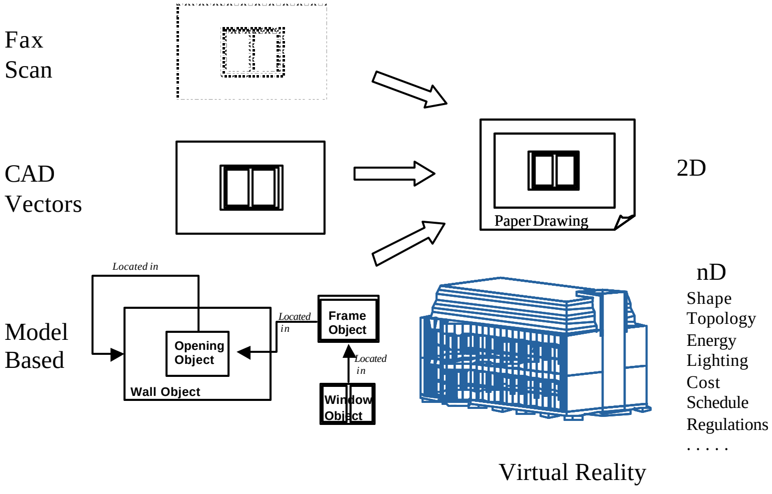
8. Model Based Information

Along with the evolving Web (in chapter 6), model based information is a technology-enabled business transformation with growing potential to impact the way the construction industry works and collaborates technically.

Until the last decade, buildings and building parts were represented as dimensioned 2D drawings on paper. Information exchange and transfer was achieved by copying (dyeline or photocopy) and postal delivery.

For small (A4) drawings, facsimile (fax) transmission helped solve the problem of the delay in transfer, by instantaneously transmitting sketches and schedules. However, although transferred electronically, what was received was no more than closely pitched dots on a page which, like paper drawings, are only computer sensible when manually re-entered.

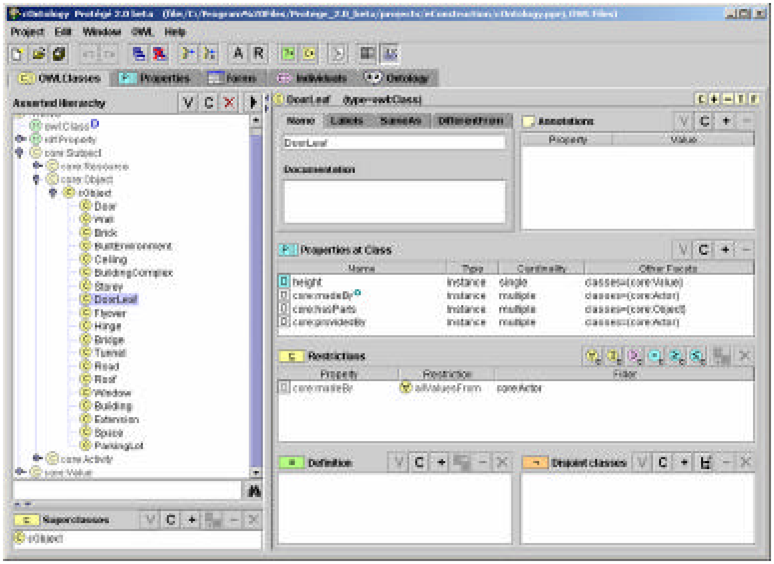




Computer Aided Draughting (CAD) became commonplace in construction during the 1990s, with the advent of affordable, high performance PCs. CAD allowed the creation of digital data via 2D (and later 3D) positioned "geometric primitives" like line, box, arc and text entities. Initially reuse was limited to the adaptation of entities (adding, deleting, changing, copying) in drawing files between the *same* (proprietary) CAD systems.

Exchange between *different* proprietary systems was facilitated by devising "neutral" file exchange standards like IGES (Initial Graphics Exchange Specification). In the construction industry, the DXF data exchange format was widely adopted for 2D exchange (taking the proprietary format of one supplier as an exchange specification for use between different CAD systems across the industry).

IGES and DXF are essentially graphic standards dealing with simple geometric primitives – a rectangle perhaps *implicitly meaning* a central heating radiator to a heating engineer or the cross section of a column to a structural engineer. However, all the computer knows about is a rectangle! CAD systems introduce limited *context* intelligence through "layering". Layering suggests physical overlays, but in fact layering consists of tagging the geometric primitives with a code that allows them to be grouped – all "first floor walls", all "foundations" etc. Counts can also be performed – "all the doors on floor 5". The use of a scale means that lengths and areas of primitives can be calculated automatically – extending CAD to perform simple quantity take-off.



2D CAD (and 3D visualisation) provide geometric representations of items, but they primarily satisfy only the appearance aspects of architecture and the architect's viewpoint. Engineers need information on the way building elements and installed components fit together into networked systems that carry the *flows* of liquids, electricity, people, structural forces etc. throughout the facility.

> *"The object world will be the nearest thing we can get to experiencing the real world before we are in it"*

A geometric view using shapes is insufficient to support engineering viewpoints and so "object modelling" was conceived in the early 1990s. The focus then became "real world" items and how their behaviours and interactions could be represented as properties, with data giving values to those properties.

Above is an example of a building object (a door leaf), with some of its characteristics, as viewed by an "object explorer".

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.

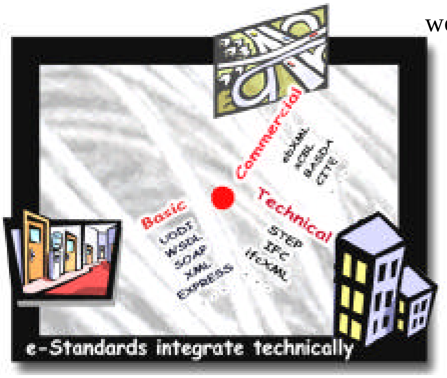
As with drawing exchange, model exchange between *different* systems requires the standardisation of "language". What is a beam? What types of beams are there? What properties of material, shape, size etc. are necessary? The approach to Product definition originated in ISO TC184/SC4 STEP (Standard for the Exchange of Product model data). It involves determining the "types of" elements that exist that then become templates for individual instances of them in a real facility.

The work of information modelling is labour intensive, requiring considerable experience. Moreover, the results must be internationally agreed in the new global marketplace. Thus it seems appropriate for the workload to be shared internationally. The task of "modelling the construction world" has been assumed by the International Alliance for Interoperability (IAI), supported by several past and present EU projects and national research & development efforts in Europe and internationally.

Many objects have been defined (in IAI terms as Industry Foundation Classes, IFCs). A significant number of software developers and vendors have developed communication interfaces to write/read IFC exchange data for applications as diverse as energy, structures, architecture, costing, acoustics and time scheduling. www.IAI-international.org lists some of these applications.

9. e-Standards

e-Standards encompass all the generally accepted technical approaches to interfaces and data structures facilitating electronic working (eBusiness, eCommerce, eGovernment). One e-Standard for everything would be convenient, but this is not the case. Standards are tailored for different aspects of e-working and are relevant to different process stages.



In the past ISO, European CEN and national bodies like AFNOR, BSI and DIN managed standards development. Standards evolved retrospectively by consensus of good practice. Now, in fast changing areas, standards may be:

- *competitive*: similar standards evolving until one dominates
- *pre-emptive*; new standards that anticipate the communication needs of new products, processes and systems
- *collaborative*; with industry consortia aiming to short circuit the approval processes of formal standardisation.

Bodies developing e-standards include the International Standards Organization (ISO), the International Alliance for Interoperability (IAI), the Organization for the Advancement of Structured Information Standards (OASIS), and the World Wide Web Consortium (W3C).

Some construction processes are regional (local to a country) and the development of supporting e-standards must then be local e.g. CITE is setting standards for cost and tendering in UK, with the GAEB doing the equivalent in Germany.

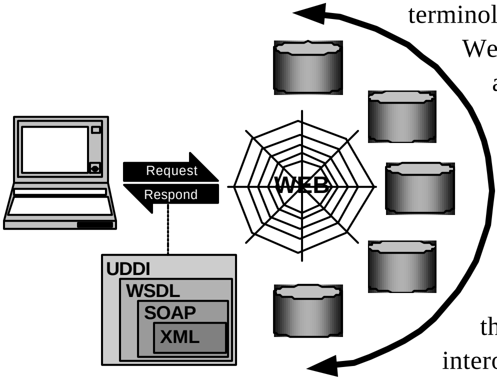
Basic Standards

Basic standards provide the foundation for communication and integration. They range from standards that define the syntax of information communication to those that apply structure and constraint to the form of that information. Basic standards define how information may be communicated (the format), not the meaning of particular communication.

Basic standards related to the **World Wide Web** include (amongst others):

HTML	HyperText Markup Language for the presentation and display of web pages
XML	eXtensible Markup Language specifies tags to identify types of data (semantics)
SOAP	Simple Object Access Protocol. A lightweight XML-based messaging protocol to encode Web-service requests/ responses sent over a network.
WSDL	Web Services Description Language. An XML-formatted language to describe Web-service endpoints for messages.
RDF	The Resource Description Framework is a language for describing information metadata on the WWW such as title, author, Web page modification date etc.
UDDI	Universal Description, Discovery and Integration is a global web-based directory listing businesses on the Internet, like a yellow/white pages directory.

Along with base standards for the meaning of terminology (such as Ontology Web Language, OWL) the above standards are key to the development of the "**semantic web**". This is a new concept to connect distributed applications and data on the Web that is driving the development of interoperability standards (different applications or data working together).



In addition to web standards, the basic standards for product model data exchange defined within ISO 10303 include:

Part 11 (known as EXPRESS)	The data definition language for all ISO product model data exchange standards in industrial automation.
Part 21	The syntax for the clear text encoding of data files structured according to an EXPRESS data model.
Part 22	A standardised means to access data in a database (the Standard Data Access Interface, SDAI)

Product model data describes the characteristics, properties and relationships of (mainly physical) items e.g. in our construction world.

Business Standards

Each standard defines the 'ontology' of objects and relationships in a particular business context. Ontology (how we talk about things) provides the language to express knowledge consistently e.g. for a future "construction semantic web". Business standards cover both technical and commercial exchanges.

Technical Standards - the current key technical standards for product modelling in building construction are:

IAI/IFC	IAI Industry Foundation Classes; for the building lifecycle. Also in XML form (ifcXML) a candidate standard for XML use in building construction.
CIS2	The CIMsteel Integration Standard for information exchange across the structural steelwork supply chain.

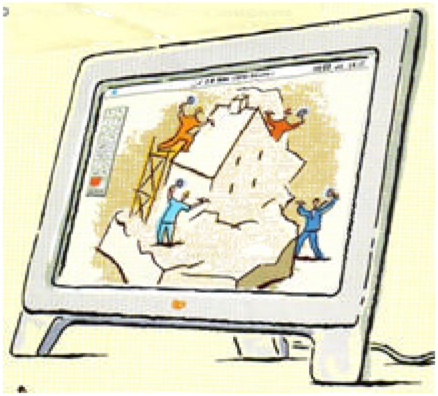
Commercial Standards regulate the commercial and administrative messages/data in projects. There are several (partly overlapping) standards for a range of common commercial transactions supported by individual XML schema. The main standards are:

ebXML	Electronic Business eXtensible Markup Language (ebXML) A UN Centre for Trade Facilitation and Electronic Business (UN/CEFACT) and OASIS initiative to define XML e-business implementation in the global marketplace.
xCBL	Schema for common business transactions derived from an earlier CommerceOne database implementation, made public. xCBL is widely used in portals.
cXML	cXML transactions are simple text file documents containing values enclosed by predefined tags. cXML documents are analogous to paper pro-forma used in business e.g. Purchase Orders.

If you do not understand the detail above (and you will not be alone!), just realise that 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!).

A Knowledge-Centric Industry

This final section draws conclusions from the earlier chapters and takes a look at life and ICT in the not so distant future . . .



10. Knowledge Use

We 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 for future use. Too often when a project ends, so too do the memories of lessons learned and experiences gained.

Today, many (of us!) are simply overwhelmed with information and are too busy to share what we know. What precious time we do have, we spend searching for "needles of information in information haystacks" (i.e. document archives!).

Experience is the capital worth of both individuals and organisations. Experience (our knowledge) needs to be handled properly so as not to "reinvent the wheel" on each new project and to also avoid repeating past mistakes.

In the beginning, knowledge is unstructured and scattered (amongst people and systems). The right management vision and resources (interest, encouragement, incentives, rewards, pats on the back etc.) can stimulate the structuring and use of valuable knowledge.

Experience will often be in the form of anecdotes in the heads of individuals., but it can be partially structured as, for example, rules of thumb. More structure and meaning is added when it is made available in some tangible form to others (for example, the project debriefing of chapter 1). It becomes fully structured (explicit) when it can be established as a set of proven rules formalised for use by others. Sometimes new knowledge is created out of existing knowledge – knowledge as a life form! Different mechanisms and instruments enable the exchange of knowledge across the divides of tacit-to-tacit, tacit-to-explicit., explicit-to-explicit, and explicit-to-tacit.

Proper handling of knowledge requires its identification, collection and organisation (the cost/effort side) but will then facilitate sharing, adaptation, use, and creation of new knowledge. (the benefit side). Remember that in construction we do not sell products, we sell "our" knowledge to make them.

Knowledge tends to be best handled through communities, not just libraries or document management systems. Knowledge distribution is foremost a social action and next a technical (enabling) process. Two basic forms of communities for knowledge sharing exist: digital communities and social communities.

Within *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). Individuals will search

for a relevant document or expert through search mechanisms, or have relevant information delivered to them (for example by asking for notification whenever a particular building standard is updated.) So, digital communities connect people and knowledge sources (e.g. documents).

Social communities have always been the preferred way to share knowledge in our industry. Like-minded people come together to share "stories" of their experiences. Knowledge sharing has often taken place at informal gatherings. "Last week we were pouring concrete for the foundation when the crane was struck by lightning, but we just carried on and finished the job by hand"! Such stories are typically recalled when people face a similar problem. It is not on paper, but passed informally one to another..

It is said that "success has many parents but failure is an orphan". However, both *success and failure* are integral parts of the intellectual capital of organisations and individuals. Otherwise, how can it be ensured that not only will good practice circulate amongst but that mistakes will not repeated by them.

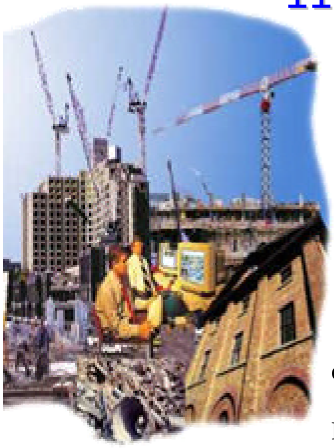
Effective knowledge sharing, is a MUST in our industry … it always has been! We need to take on board the right tools to ensure we have the right information when we need it, not to go diving into those haystacks!

There is no fixed recipe or single tool for knowledge sharing. It all depends on the organisation and the people involved. Some tools and techniques have been mentioned in earlier chapters of this book. Many proprietary systems for many different uses are available on the market, and there are many more on the way to both handle knowledge and to help visualise it. These are important tools because they facilitate team working and help to mould teams.

Most successful organisations have adapted particular software tools and working techniques to their own needs. Foremost however, they have ensured that people mix and talk together. Without the willingness to acquire and share knowledge informally (perhaps over a beer!) available knowledge that exists will not, indeed cannot, be used.

The effective storage, retrieval and reuse of information and knowledge, sustaining teamwork, remains a hot research and development topic. Rightly so, in view of the potential value. Knowledge of what ICT can and cannot achieve is part of that, but social interaction in the workplace - people mixing and talking together - remains an absolutely essential ingredient.

11. Construction eVolution



The previous chapters introduced many trends indicating some of the 'ways to go' in Construction ICT. These trends complement each other but often build upon and strengthen one another too. In this chapter we consider the relatively near future when the Internet and the World Wide Web will play major "integration" roles combining trends and supporting the working lives of construction practitioners.

First, the earlier themes of future Construction ICT or 'eConstruction' are reviewed.

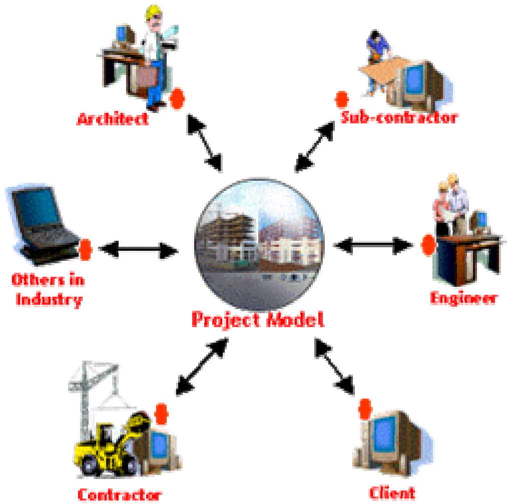
Knowledge Management

The ideal is seamless communication of project information through the whole construction project lifecycle and the trading supply chains. Up-to-date information is always and everywhere available for all participants involved in all product aspects, at the levels of detail required. Each actor can work *reliably* on the input of others and generate new value-adding information from his expertise that can in turn be used by others. In the construction world 90% of work involves processing of information, so it is worth every effort to turn "current friction into future flows".

Integration

Integration, interoperability, open standards all refer to the ability to communicate internally and externally with others via computer systems, enabling people to cooperate and collaborate. Achieving this is not easy, even in a single company that has a mix of multi-vendor software applications (an optimal single vendor one-stop-shop is unlikely to ever exist), but it is a greater challenge when talking to clients, partners, subcontractors and suppliers each with their own mix of applications. It is clear that agreements on 'what' and 'how' to communicate are essential for improved ICT-based teamwork - and agreement is needed worldwide for doing business across borders.

Following the standardisation spirit of ISO STEP, the International Alliance for Interoperability (IAI) has developed IFCs (Information for Construction), offering "information rich" object data exchange for all actors over the whole facility life cycle. This is supported by many construction industry ICT vendors. Currently the language



used is primarily STEP-based but it is now also embracing XML. However, irrespective of the technologies, the important task is to specify the construction "objects-of-interest".

Model-based

In the future there will be less paper. But just going digital is not enough. Instead of documents and drawings needing human expert interpretation there is a shift to models that describe the real (construction) world via parametric objects; a way that makes sense not only to humans *but also to the computers supporting them*. Software being smarter (or having more semantics, to use a technical term).

Humans are good at interpretation, but also doing it wrongly! So, the shift to intelligent, model based technology should reduce mistakes.

Object-oriented

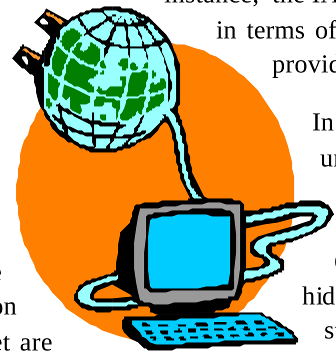
This technical term (not to be confused with model based objects) has its origins in computer programming. The underlying question is familiar - what is more important, the Process or the Result? (chicken or egg!). As usual, the truth is somewhere in between. In ICT this truth is referred to as object orientation, addressing simultaneously, and in an integrated way, both data and functionality aspects.

The big World Wide Web Enabler

Looking at the Knowledge Management wish-list it could be concluded that no action is necessary to find a further solution since almost everyone has free online tools to access shared information on the web. Because the Web and the Internet are based wholly on Standards, everybody can in principle access information in the same way. By speaking the same Language (IP, HTML, URI, XML, …) there is, in a technical sense, already some integration. The current Internet and Web is *the* information infrastructure and this is not expected to change for some time.

The Web is a seemingly ideal platform for doing Knowledge Management and Integration, but it is not model-based or object-oriented. Independent of the construction industry, the World Wide Web Consortium (W3C) has acknowledged these precise requirements and has already included generic solutions in the “Next Generation” Internet that should meet our needs.

The Semantic Web is the result of extending the present HTML-based Web to a model-based capability. Now data on the Web can be directly meaningful to software applications as well as people. The Semantic Web will provide the language for both the meaning and the form of intelligent data in a very flexible way. Freely available Semantic Web browsers and search engines will enable anybody to use these new technologies. W3C will need to draw upon the special construction semantics that are already inherent in, for instance, the IAI IFCs. They will be translated in terms of the Semantic Web Language provided.



In fact the Semantic Web is an umbrella for a bunch of technologies (with acronyms like XML, XSLT, RDF(S), OWL that thankfully will be hidden from users!). The data structures called ‘schemas’ in STEP and IAI are in semantic web terminology ‘ontologies’ that can be distributed over the web so that anybody can maintain a personal view of core information convertible to their own country language and terminology.

Object-Orientation is another promising technology advance getting attention through the development of Web Services. Until now users have themselves accessed and controlled functionality over the web (e.g. for banking or travel booking). With Web Services, software applications will do the same thing but without human intervention!

Again a large suite of interrelated standards and acronyms underlie Web Services (UDDI, WSDL, BPEL4WS, SOAP . . .). Though off-putting, these acronyms are perhaps less frightening when translated into everyday metaphors. We want to be able to describe

a) the basic services software can do for us (Web Services Definition Language) over the Internet/ Web (in a Simple Object Access Protocol envelope), and

b) more complex combinations of services making up the whole business process (defined by Business Process Engineering Language for Work Specification)

Moreover it is convenient to publish a public "digital yellow pages" directory to identify pre-existing Web Services that do the kinds of tasks individual users require (Universal Description, Discovery and Integration). Again, existing semantics such as those incorporated in ebXML (electronic business XML) will need to be translated for use in these new semantic technologies.

The intention is that the right mix of Semantic Web and Web Services will result in the future platform that is required as the backbone for the improved Knowledge Management and Integration described earlier.

Jump into the Future

We currently perceive only the fringes of the future of Construction ICT. Consider what has occurred over the past decade and try to imagine what the situation might be in ten years time when all devices are connected wirelessly (enabled by any mix of technologies like Bluetooth, WiFi and UMTS or some other 'Ultraband' technology not yet invented).

Imagine that every physical construction item could identify itself via built-in, radio-based chips (AUTO-ID) before, during and after construction, forming an 'Internet of Things' connected into the Semantic Web. Further still, imagine improved security and trust, payment systems, web-based simulation and visualisation (like SVG & X3D). Combine all these with probably a second generation of Semantic Web Services. Last, but not least, consider implementations arising in the open source software domain.

The technology future of ICT can hardly be imagined let alone predicted. 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.

12. Impacts & Benefits

This chapter presents an overview of some of the drivers for change in the industry and the responses in terms of new ICT supported processes and the anticipated 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.

Supporting this, the adoption of information technology is leading construction disciplines to become **more open and trusting** of each other by sharing project information electronically. 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, a declining product quality, in some countries fuelled by skill shortages, has prompted action by clients and main contractors to consider ways to better foster skills and to invest to raise productivity.

Cross-discipline communication between the many design, contracting, sub-contracting, supply and client interests is often problematic and a major contributory factor to poor project performance (as referred to in chapter 1).

How can **communication be improved**? The medieval architect and engineer Giuseppe in chapter 2 was certainly not able to be everywhere, nor could he be in control of all he wanted. Today he could have been – **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**, introducing the possibility for globally distributed design teams and 24 hour design. Indeed in some large international projects it is already happening, and it is perhaps just a matter of time (in fact, time to change culture) before it begins to happen lower down the scale of projects. Interpersonal communications have been revolutionised – at a **cost affordable by almost all organisations**, and even individuals.

Also crucial to the realisation of any construction project is the passing of project information within and between disciplines and organisations. "**The outputs of my part of the process become the inputs to yours**". Historically, drawings and specifications have been the means of formal inter-organisational communication of project information. Keeping different drawings and specifications "coordinated" (up-to-date and consistent) is a major task but lack of coordination (out-of-date, inconsistent information) is the root cause of wasted time, materials, effort and money – and disputes between parties.

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 (IIMS) are a means to order information (e.g. electronic documents) for ready access and retrieval anywhere, anytime, by anybody. Integrated project teams are thereby supported with participants able to select only that information which is relevant to their work and its context. Stored information is tagged with meta-data (data that classifies and describes document and files). With the appropriate access rights, participants can see the latest information – proposed, awaiting comment, awaiting approval, issued etc.

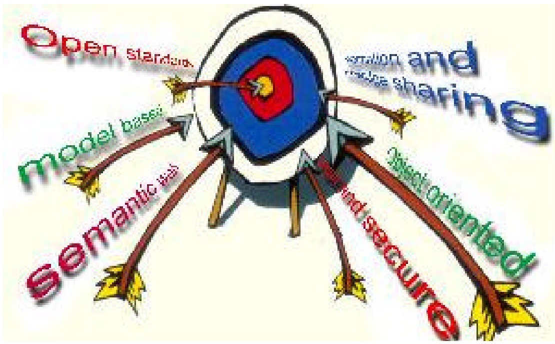
The next stage is to fully integrate data, effectively combining the data and information content of **drawings** (size, relationship, position and composition of construction elements), **specifications** (material, performance, manufacture), **schedules** (time, resource, cost) and **reports** (technical, management, financial etc).

In other words, **information aggregated around an object not attached to its representation** (drawing, document etc). This has been a major goal in many industries, including construction, involving bodies like the International Organisation for Standardisation (ISO), European CEN and the International Alliance for Interoperability (IAI). The EU strongly promotes open standards and the Open Source Software Foundation (OSSF) is even nurturing the concept of "free" software.

Why is all this openness important in the context of software applications used today? Data is currently tied to proprietary software applications; forcing use of that software. Exploiting data for other purposes in other applications requires considerable technical expertise. Openness equals choice and flexibility.

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 stage 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.



So, 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

13. Time Telescope

Chapter 1 was an account of a typical project's performance. This chapter begins with a (possible) scenario for Ken's successor, Rob.

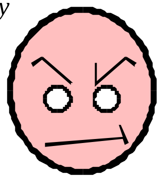
The **Client** pulled into the motorway services in advance of a scheduled video-call. He joined the discussion, now displayed on the dashboard console. The agenda scrolled at the bottom of the screen. The Client scribbled on his electronic notepad, sometimes cross-referencing notes to specific displayed charts.

Moderating "virtual" discussions was not always easy for the Project Director, **Rob**, but the participants knew each other well and the occasions he overlooked people were taken in good humour. The discussion ended and Rob asked everybody to forward any public notes so he would not miss points in the minutes.

The Client drove on to his Board Meeting and Rob considered the points that had been made. He broadcast a request for a face-to-face design meeting within the next week with the project architect, structural engineer and site manager. The electronic diaries quickly responded. The ideal was not possible and Rob had to settle for himself, the site manager and the engineer meeting on the following Thursday, with the architect virtually present.

Thursday came. Rob asked **Frank** to take control of the model remotely, "You know the layout inside out", he commented. The wall in Rob's office came to life and the as-designed model of the future Chepton Phase 2 appeared

"The Client wants to move the lift shaft a couple of metres to the right", Rob advised, "It means longer floor beams to the left, of greater depth or with more reinforcement. I don't think he appreciates that *beams are like people – they don't like change*!". They laughed, but the point was serious - construction was due to start in the immediate zone in two weeks.



Rob suggested they review groundwork progress and selected the site from his desktop menu. An aerial view appeared, and a superimposed 3-D model showing the locations of other cameras. As building progressed and camera positions changed their locations were known automatically by GSM positioning.

Since the site manager had left site the day before, groundwork had progressed significantly. A quick evaluation of the change request was needed. Frank brought the building model to the screen. Copying the coordinates of the change from the camera view to the clipboard, he next pasted them in the Zoom-To field of the modelling system. The lift shaft, beams and slab were clearly apparent.

The structural engineer, **Gisela**, took control to extract structural properties from the model and do initial beam sizing on her electronic Calc-Pad, investigating the likely impact of the change. Simultaneously, Frank checked conformance of the new layout to the evacuation regulations using code-checking software.

A nice story, but pause for thought . . . . .

Above:

Beware of short term actions based on "only" short term thinking.

The "desert islander" has a new house, but what about his food source of coconuts? Perhaps he sowed some seeds!

How realistic is this scenario?

It depends on *your* viewpoint. From the technology perspective all is practicable - the hardware, software, standards etc. exist. The probable practitioners' viewpoint is that it is futuristic and its value possibly 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.

Do we (do I) have to be concerned about all the different strands of technology?

There's a lot of "generic" hardware in the scenario and services like GSM. Our concern is technology that we, not others, must provide.

- We must take responsibility for our own needs and our own affairs.

But it's simply not practicable for industry companies to develop software themselves!

True. 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 projecting that is part of our responsibility as industry associations and companies.

- Software houses respond to industry leads, but can be proactive in "lighting the way".

Is there one technology I should attend to?

Yes. Model Based Technology. Underlying most cameos in the scenario is intelligence – objects (beams, cameras, locations. . .) knowing a lot about themselves and how they relate one to another. This technology integrates information and facilitates collaboration.

Is this technology unique to construction?

No. It is relatively common technology in advanced industries and business sectors. What is unique are the internationally agreed objects and properties with which we deal.

- Think objectively!

What can it do?

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; health, safety and environmental assessment etc. Different specialists/applications pool information though detail may be held privately in different places.

What can I see?

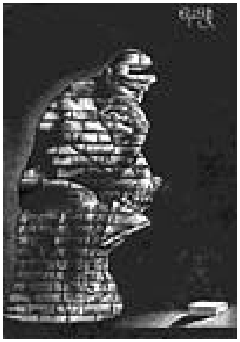
Arguably the most impressive and easiest examples to follow are those that manipulate models in 3D. Those that reveal deeper potential compute complex flows (forces, heat, people etc) and "size" the visible components.

Where can they be seen and tried?

Vendors willing to demonstrate and allow you a "hands-on" session are listed at the web-sites on the inside front cover. Also listed are organisations pleased to assist by email.

- Technology is not the starting point. Look at the process; look for inefficiency and waste; then look for solutions.

Contacts, References and Further Reading



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ISTforCE	*Intelligent Service Tools for Concurrent Engineering*	Prof. Raimar Scherer Dresden University of Technology, D Scherer@cib.bau.tu-dresden.de
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OSMOS	*Open system for inter-enterprise Information Management in dynamic virtual environments*	Prof. Yacine Rezgui University of Salford Y.Rezgui@salford.ac.uk
eConstruct	*eCommerce and eBusiness in the European Construction Industry*	Jeff Stephens Taylor Woodrow, UK jeff.stephens@uk.taylorwoodrow.com
e-COGNOS	*Electronic consistent knowledge management across projects and between enterprises in the construction domain*	François Giraud-Carrier Derbi, F f.giraud-carrier@derbi.fr
e-LEGAL	*Specifying Legal Terms of Contract in the ICT Environment of Construction*	Dr. Tarek Hassan Loughborough University T.Hassan@lboro.ac.uk
GLOBEMEN	*Global Engineering and Manufacturing in Enterprise Networks*	Martin Ollus VTT Technical Research Centre of Finland Martin.Ollus@vtt.fi
SPICE	*Specifications for Integrated Construction E-standards*	Dr. Michel Böhms TNO Building & Construction Research, NL m.bohms@bouw.tno.nl

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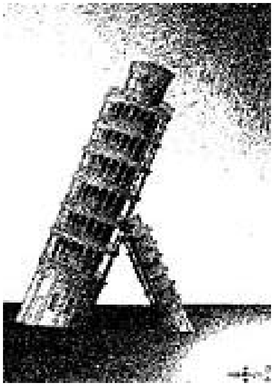

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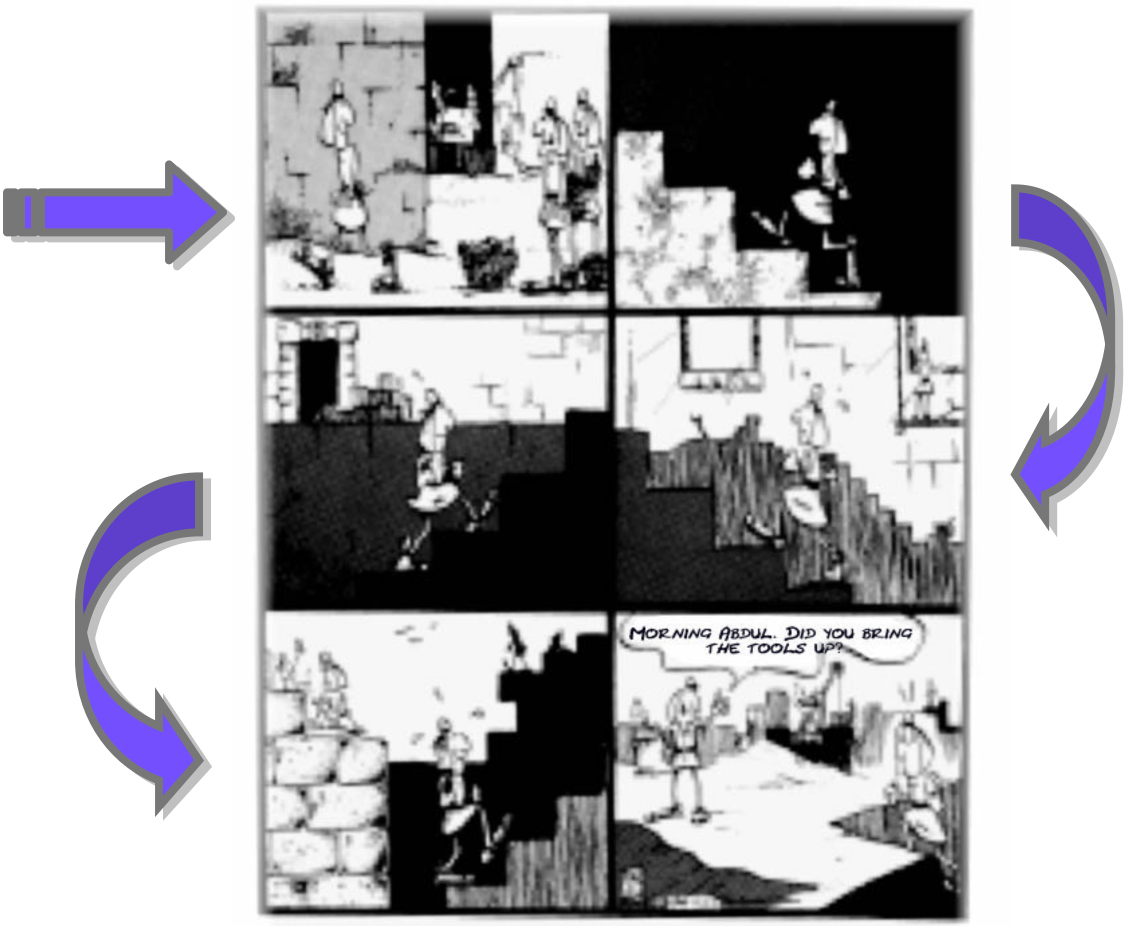
15. Glossary

The glossary explains many ICT terms not already defined in the text. The majority are not construction specific and most will remain hidden from users of software applications and systems!

Construction ICT	ICT	*Information & Communication Technologies (IT generally, telecommunications, the Web . . .)*
	CAD	*Computer Aided Draughting (2D or 3D). Sometimes, Computer Aided Design*
	Interoperability	*The ability of computer applications to exchange and share information.*
Internet & Web	+ Intra- & Extranet	*Networks of computers – public, private organisation, private community (a project association)*
	WWW by W3C	*World Wide Web (on top of Internet). Developed and supported by World Wide Web Consortium*
	HTTP	*HyperText Transfer Protocol, the World Wide Web protocol standard that defines message formatting, message transmission, and Web server and browser actions.*
	URL	*Uniform Resource Locator, the address for a file or page on the Internet (where to find it)*
	XML	*eXtensible Markup Language, to define and exchange structured information in Web applications.*
Business Processes / Transactions	WfMC	*Workflow Management Coalition: International group of vendors, users, analysts & researchers developing workflow and standards for terminology, interoperability and connectivity.*
	EDI-ebXML	*Electronic Data Interchange and its modern counterpart Electronic Business XML. Framework for eCommerce from a process-oriented viewpoint.*
	EAN	*European Article Number. Number / bar code uniquely identifying vendor product types. Soon to be followed by RDIF, radio-based and uniquely identifying individual occurrences of products.*
	(UN)/EDIFACT	*(United Nations) Electronic Data Interchange for Administration, Commerce and Transportation.*
	OASIS	*Organisation promoting e-Business standards. Like ebXML. http://www.oasis-open.org/*
	CEN/ISSS eBES	*An European CEN standardisation group establishing ebXML (electronic business XML)*
	XSD	*eXtensible Schema Definition: Language for defining structure of XML files. Itself defined in XML http://www.w3.org/XML/Schema/*
	OWL	*Ontology Web Language: RDF(S) with more ontology expressiveness. For software that processes information content not just presenting to people. http://www.w3.org/2001/sw/WebOnt/*
(Semantic) Web Services	Semantic	*Connected with meaning of words or sentences Semantic Web: http://swws.semanticweb.org/*
	RDF(S)	*Resource Description Framework (Schema). Language to describe semantics (often in this context referred to as 'meta-data') of XML files (beyond structure). http://www.w3.org/RDF/*
	UDDI	*Universal Description, Discovery and Integration: Provides a standardised basis for companies and applications to dynamically find/ use Web services over the Internet. http://www.uddi.org/.*
	WSDL	*Web Services Description Language: defining services offered by Web Services. WSDL separates abstract functionality from concrete description such as "how" & "where" functionality is offered.*

	BPEL4WS	*Business Process Execution Language for Web Services: Language to combine Web Services into processes. http://www-106.ibm.com/developerworks/webservices/library/ws-bpel/*
	SOAP	*Simple Object Access Protocol. Technical XML-based communication layer over the web (HTTP+). Often implemented in HTTP or SMTP (e-mail). http://www.w3.org/2000/xp/Group/.*
	PDA	*Personal Digital Assistant: Handheld computer integrated with mobile phone and internet access.*
Mobile/ Wireless	GSM	*Groupe Speciale Mobile: Mobile telecommunication for mobile telecommunications.*
	GPRS	*General Packet Radio Services, an extension of the GSM standard for higher transmission speeds*
	UMTS/WiFi/ Bluetooth	*Evolving mobile technologies with different ranges/roaming capabilities/speeds. One of the enablers of so called "ambient" ICT.*
Product Modelling	ISO 10303	*An international standard that defines the basis for "Product Data Representation and Exchange" Standardised data exchange standards for a number of industries. (aka ISO STEP)*
	EXPRESS	*Widely used data modelling language (ISO 10303 Part 11) expressing data and relationships.*
	SPFF	*Step Physical File Format: ISO 10303 (Part 21) format for data exchange based on file transfer.*
	IAI	*International Alliance for Interoperability: International coalition of construction organisations, vendors & researchers specifying the IFCs. http://www.iai-international.org/iai_international/.*
	IFC	*Industry Foundation Classes (Information for Construction): Object oriented information exchange specifications for Architecture, Engineering & Construction and Facilities Management.*
	ISO 12006-3	*Draft international standard for defining construction related object libraries. http://www.icis.org/tc59sc13wg6/index.htm. Adopting traditional ISO STEP methodology.*
	eConstruct bcXML	*A European R&D 5th framework project developing specifications (bcXML) to describe construction products. Similar to ISO 12006-3 but using modern semantically enriched technologies.*
	LMO	*Language for Modelling Objects: Generic version of both eConstruct bcXML and ISO 12006-3. with improved semantics and flexibility utilising new semantic web technologies (OWL, RDF(S)).*
	Web 3D Consortium X3D	*eXtensible 3D Graphics. XML version of Virtual Reality Modelling Language (VRML). Web3D Consortium (Internet development community). http://www.web3d.org/x3d.html*
	Data Sharing	*Common access to data in a repository by different applications that create, use and update data.*
	Model-based	*Building system represented by a computer interpretable model for data exchange and sharing.*
	Open Standards	*More than a public specification. The way of promoting a standard makes it open*
	Ontology	*"What exists" - explicit specification of a conceptualisation; a collection of interrelated concepts.*
	Object-Oriented OO	*Programming paradigm in which things are modelled/implemented as Objects with Relationships*
	Knowledge-based systems	*Information systems that interpret and reason knowledge in the form of rules, derivations etc. beyond factual data. Knowledge management gathers, organises, shares and analyses knowledge*



WORKING ON THE TOWER OF BABEL

Having the right tools, in the right place, at the right time

16. Acknowledgements

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Many organisations and individuals have contributed to this booklet:

The ICCI Partner organisations

Centre Scientifique et Technique du Bâtiment	F	www.cstb.fr
University of Salford	UK	www.salford.ac.uk/isi
Technical Research Centre of Finland	Fi	www.vtt.fi/cic
TNO Building and Construction Research	NL	www.bouw.tno.nl
Technical University of Dresden	D	www.tu-dresden.de
Loughborough University	UK	www.lboro.ac.uk
University of Ljubljana	SI	http://itc.fgg.uni-lj.si
AEC3 Ltd	UK	www.aec3.com
Technical University of Delft	NL	http://cti.ct.tudelft.nl

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The principal individual contributors were:

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Terry Rewcastle (pages 7, 8, 34)	UK	Cartoons
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Alain Biltereyst (cover, pages13, 37)	B	Cartoon

The co-ordination, transfer and deployment of Innovative networked Co-operation in the Construction Industry **(ICCI) concerns the review, analysis and synthesis of European Information & Communication Technology (ICT) developments for the Construction Industry sector.**

The Industry is dominated (95%+) by dispersed, small and medium sized enterprises (SMEs) that undertake the design and construction activities, and provide most of the specialist architectural and engineering software. In this, clear, responsive and accurate communication is essential.

This booklet presents a view of the role of ICT, present and future, in building better communications, processes, relationships, tools and management that will support European construction enterprise worldwide.

The scope of ICCI and the content covered by this booklet include:

- **Construction Industry requirements and needs in global eBusiness**
- **ICT infrastructures for construction projects**
- **Human and organisational issues of ICT adoption and use in construction**
- **Legal and contractual aspects of networked co-operation in projects**
- **Dissemination – spreading awareness to Industry and R&D communities**
- **Strategy and future plans for ICT in construction**

The Authors would welcome contributions, particularly from Industry practitioners and software vendors, that add to, extend, illustrate or even contradict views expressed by ICCI. Please send to Alain.Zarli@cstb.fr who will distribute within the ICCI partnership.

http://icci.vtt.fi