# ENHANCING THE COMPETITIVENESS OF THE EUROPEAN CONSTRUCTION INDUSTRY IN THE DIGITAL ECONOMY

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## ABSTRACT

*Funding bodies in general, and the European Commission in particular, have for over a decade funded project centred Research and Technology Development (RTD) efforts. While these have traditionally operated in isolation with little co-operation and cross-fertilization of results, a crucial requirement has emerged, following the latest advances in Information and Communication Technologies (ICT), to have a more concerted and co-ordinated action aiming at a better integration, standardisation, dissemination and exploitation of the results from these projects across the European regions and countries. This has been clearly identified as a key requirement within the European Information Society and Technology (IST) Programme. In that respect, based on the promising results and achievements realized by the leading Construction IT community in Europe, a cluster project involving six IST funded projects has been set-up in order to achieve a better integration of research results in the area. This project, ICCI (IST-2001-33022), is targeting a specific sector: the Construction industry, and is addressing a wide spectrum of issues ranging from ICT implementation and deployment to organizational, social, and legal aspects. The paper gives (1) a background description of the context in which ICCI operates, (2) its aims and objectives, (3) the research results achieved to date by its partners within their respective IST project, and (4) a road map identifying areas of collaboration and expected impacts in the European Construction digital economy.*

## 1. INTRODUCTION

Construction is an important sector of the European industry (8%+ GDP and over 8% civilian employment), highly fragmented, involving a majority (over 95%) of SMEs (European Commission, 1997). The Construction industry is project centred and characterized by short-term partnering between non co-located teams with varying levels of process maturity and ICT capability. The industry is known for its conservative culture with a relatively high resistance to change. Although the larger industry players at the management level undertake construction internationally, the vast majority of work is done by local or national SMEs, often also under local building regulations and standards.

Various policies promoted by the European Commission (EC) emphasise the critical importance of the future digital economy to European businesses, particularly in establishing a flexible, adaptive business environment (European Commission, 1997). The construction industry is nearly unique in its dependence on SME working teams. However, SMEs (who own most of the construction industry skills) cannot afford to invest individually in advanced developments. They often rely on (largely national) trade associations to look after their medium and long interests, whilst focusing themselves on more short-term improvement timescales. The nowadays requirements for permanent innovation and the new challenges for competitiveness must lead European construction companies to enrich and exploit their competencies and knowledge as best as possible. It is one of the roles of the European RTD efforts to help these companies achieve this vision by:

- Providing networks and forums for knowledge exchange within the academic community.
- Transferring competencies and know-how from the European academic community towards European companies, including SMEs.
- Helping these companies/SMEs to use tools, platforms and services that are oriented towards the needs and activities of the professionals in industry, including the potential, partial or total, integration of their own information systems within such platforms and Web services.
- Promoting the technological and economical development of regional companies in Europe, i.e. help them to optimise their ways of working through e-services, but also allow them to increase their incomes.

This is the context in which the ICCI (Innovation co-ordination, transfer and deployment through networked Co-operation in the Construction Industry - IST-2001-33022) project was set-up, involving key partners from the European Construction industry including, CSTB, TNO, University of Salford, and VTT (the complete list of partners can be found in http://icci.vtt.fi/). The ICCI project addresses the perceived need for a Cluster project at the European level that leverages the contributions from a number of RTD projects that deal with both complementary and overlapping aspects of ICT in the Construction sector. This includes, most importantly, issues related to networks communication (e-mail and Web facilities, in house Intranet sites, inter-enterprises communication, etc.), mobile communication over the Internet, and open standards within and across companies. The projects forming the ICCI cluster all relate to the creation, sharing and use of electronic information amongst the distributed participants in construction projects – i.e. contributing to the establishment of a "digital domain" for construction. The project started on 01/09/2001 and is expected to end on the 31/12/2003.

## 2. THE ICCI PROJECT

There is today a crucial need to harmonise, integrate and disseminate the current European research and development efforts. The ICCI project is about trying to establish a critical mass of European involvement to meaningfully start the process of change that is now required in the Construction sector if it is to remain competitive in today digital economy. The ambition of the ICCI initiative is to build a cluster upon a set of IST funded projects related to IT in construction, with the aim to (1)

improve harmonisation and coherency of research and development, (2) assist knowledge transfer to industry, and (3) reduce time to market of exploitation. Indeed, deploying and using IT in construction is nowadays less a matter of cutting edge technology, than a combination of technology, organisational, marketing, legal frameworks and social impacts. It is the objective of ICCI to start paving the way to such combination for the construction sector.

Collectively, the ICCI clustered projects represent 203 person-years of effort. ICCI includes those national research and academic organisations that have been (and are) most active in the field of construction ICT and have demonstrated outstanding research capabilities within their field. They have the strategic ability to contribute and impact on standardisation efforts nationally as well as internationally, and have the capacity to disseminate / exploit the ICCI results and recommendations across their respective countries as well as the various economic / cultural / geographical regions in Europe. Moreover, the ICCI consortium involves:

- partners actively involved in providing, supporting and disseminating ICT related applied research in the building and construction domain within their country (CSTB, VTT and TNO);
- partners that are key players in national as well as international standardisation committees and that have the ability to impact on standardisation efforts (CSTB, VTT, TNO, Technical University of Dresden, and the University of Salford);
- partners that have the mission of providing education at an undergraduate and postgraduate level and have the responsibility of educating the future European workforce in the Building and Construction sector (University of Salford, Technical University of Dresden, Loughborough University, Ljubljana University, and the Technical University of Delft);
- partners that provide consultancy to SMEs and large companies in the areas tackled by the ICCI proposal and have an extensive knowledge of current practices as well as limitations in the building and construction sector, and a good understanding of the market demand and requirements (AEC3).

## 3. DESCRIPTION OF THE ICCI CLUSTERED PROJECTS

This section gives a brief description of the six projects that form the foundation of the ICCI cluster project. Pointers and references are given in the text for further and more detailed information regarding these projects.

### 3.1 The OSMOS project: Open System for Inter-enterprise Information Management in Dynamic Virtual Environments (IST-1999-10491)

The general aim of the OSMOS project (Rezgui et al, 2000; OSMOS, 2001) led by University of Salford is to specify and provide a generic open platform to enable construction enterprises, including SMEs, throughout the European construction industry to enhance their current capabilities. Furthermore, the objective is to provide the necessary methods and tools to deploy quickly and easily an ICT infrastructure on projects that promotes collaboration and eWork between the various partners. This is facilitated through the ability to plug in services from third parties as well as from member actors within a construction project, quickly and at a low entry-level. Through an incremental and iterative development methodology, the project has developed, and continues to refine, a model-based environment supported by tools to set up and maintain the construction Virtual Enterprise (VE) that supports the operations of a project according to the specific agreements of the actors involved. Interim testing of the OSMOS approach has shown encouraging validation of the concepts used. The work is ongoing, and concomitant with the technological development, human and organisational issues are being addressed to ensure that the OSMOS consortium can define the likely benefits of

adopting the OSMOS approach and recommend a migration path to that end. The main outputs from the OSMOS project include:

- A Generic Virtual Enterprise Process Model describing the Virtual Enterprise lifecycle from the perspectives of the VE provider, third party service provider, and end-user.
- A robust set of models that conceptualise the underlying philosophies and business logic that enforce the implemented solution within the context of a VE.
- A Construction VE dedicated API that supports the plug-in and use of third-party services in a trusted and secured environment.
- A set of reference implementations of the OSMOS tools, including the Virtual Enterprise Manager, and a Web Information Browser used as a low-entry level tool dedicated to SMEs.
- A set of business recommendations aiming at the effective deployment of the OSMOS platform.

These results are being promoted and disseminated widely through the ICCI cluster.

### 3.2 The eConstruct project: Electronic Business in the Building and Construction Industry - Preparing for the new Internet (IST-1999-10303)

One of the major industry challenges is communication across national and organisational barriers, made even more complex due to the problems of transferring and sharing "knowledge" across different ICT systems. The eConstruct consortium, a pan-European group of construction-related organisations led by TNO, is rising to the challenge of narrowing this communication gap so that even small and SMEs can reap the benefits of using eCommerce and eBusiness effectively. The eConstruct project (eConstruct, 2001) aims to develop, implement, demonstrate and disseminate a new Communication Technology for the European Building and Construction industry, called Building and Construction (BC) extensible Mark-up Language (bcXML) (Tolman, 2001). This Communication Technology will provide the European BC industry with a powerful and low cost communication infrastructure that (a) supports eCommerce/eBusiness between users and suppliers of building materials, components, systems and services; (b) is integrated with eCommerce and Design/Engineering applications; and, (c) supports virtual market places over the borders of the individual European member states. The following applications of bcXML are being developed and demonstrated in the eConstruct project:

- bcXML support for supply-side information providing, i.e. catalogue building;
- bcXML support for shopping and buying of individual components;
- bcXML support for project related procurement involving design/engineering;
- bcXML support for Computer Aided Selling.

It is worth mentioning that support for publishing supply-side information using the Internet is currently offered by a proliferation of initiatives (portals, virtual marketplaces, and such), all using their own methods, formats and rules. Support for shopping and buying individual components over various sources of supply-side information is non-existent. Support for eProcurement directly and openly linked to a product model is non-existent. Computer Aided Selling systems that can automatically input supply-side information from different sources are also not yet available.

An eConstruct framework has been developed to test and evaluate the benefits achieved using bcXML. It is composed by a software prototype that is intended to simplify the use of the bcXML functionality and a set of "client applications" (bcXML compliant) that, indeed, take advantage of the prototype and fully exploit these functionalities.

### 3.3 The Divercity project: Distributed Virtual Workspace for Enhancing Communication within the Construction Industry (IST-1999-13365)

The Divercity (DIVERCITY, 2001) project, led by University of Salford, seeks to contribute to the improvement of the Construction design process by concentrating on three key areas of the design activities: Client Briefing, Design Review and Construction planning. It aims to integrate established Virtual Reality (VR) technologies with construction design activities in order to produce a design lead "Distributed Virtual Workspace", relying on a distributed architecture. The DIVERCITY system aims to support and enhance concurrent engineering practices therefore allowing teams based in different geographic locations to collaboratively design, test and validate shared virtual prototypes (Aspin et al, 2001).

Each of the three DIVERCITY workspaces addressing Briefing, Design Review and Construction planning have their own particular requirements, in addition to the general system requirements, which will support the domain within which the workspaces are developed. Client Briefing is predominately concerned with the communication between the client and design team/designer. The workspace must aid the designer in capturing the clients' needs and allow the designer to present design concepts to the client. Clients' needs are typically captured as text documents, often supported by sketches made by the designer in the presence of the client. DIVERCITY aims to develop 3D interactive tools to support this process. However, many of the requirements will still need to be expressed as text. The DIVERCITY system should therefore support the annotation of the design sketches with notes that can illustrate the clients' needs. The Design Review workspace within DIVERCITY looks at enhancing reviews by combining Product Modelling technologies with Simulation Environments in order to allow project teams to visualise and to interact (in real-time) with the project on a multidisciplinary basis. Continuous design is a major feature here. This means that the architectural design resulting from the conceptual design phase can be fed into the Design Review workspace and that the detailed design can be fed to the Construction planning workspace without any data loss therefore bringing important improvements to the overall process. Three key simulation features are addressed: the lighting, thermal and acoustic properties of the design. In order to display the results of these simulations the display component of the system will need to be able to integrate the results with the project data. In addition the system should also allow users to manipulate the simulation parameters, so that what-if scenarios can be evaluated from within the 3D environment, rather than having to use an external system. Construction Planning allows the designers to determine how the project will be built. Assessments about the order of construction, site safety, and location of the temporary site facilities are all operations which may be performed by this workspace. This implies requirements on the system to have a concept of time that may be linked to the design, as well as being able to set up various simulations and position objects within the 3D environment.

By its configurable and extensible features and its support to a STEP (ISO - 10303) based data warehouse (that acts as the project repository during all stages of the design / construction life cycle), this framework represents an adapted infrastructure for the development of innovative Visualisation and Simulation tools for the construction industry through the Divercity project and beyond. Future research will aim to complete the development of the framework and to validate the approach on real construction projects.

### 3.4 The ISTforCE project : Intelligent Services and Tools for Concurrent Engineering (IST-1999-11508)

The main product of the ISTforCE project (ISTForCE, 2001) is an Internet-based platform providing intelligent services and tools for an engineer participating in several projects simultaneously. The developed approach will enable to plug-in different IT tools on the platform, both directly (as core services), or as extended rented engineering services. Such tools may use conventional numeric algorithms or advanced knowledge-based methods. An important part of the research work is

concentrated on multi-project workflow management. Another important aspect targeted is to provide and manage the knowledge needed by the end-users of the platform in easily understandable form. For the harmonisation of the user interface to the different services that will be accessed concurrently through the platform and for the access to product model data, an engineering ontology is being developed and implemented. ISTforCE supports the new paradigm of user-centred e-working and complements the old paradigm of project-centred virtual enterprising.

Central to the ISTforCE approach is the concept of an open, personalised Concurrent Engineering Services Platform (CESP). The platform provides the end user with access to arbitrary services and tools available on the Internet, that he needs to solve his engineering tasks. He does not have to care as to where these tools are actually located. Tools can be plugged into the platform and are registered by an information service. They are flexibly exchangeable. They can either be downloaded and hosted at the user's desktop or they can be accessed remotely. An e-Commerce service with a billing component takes care about the financial aspects, and a training and on-line human support service provides continuously accessible help about any IT aspects of the platform. Furthermore, the platform can provide the end user with easy access to information and data from different project servers. The interoperability service manages data and information operability and a knowledge-based model access service provides an engineering like communication interface (Scherer et al, 1999) based on a new engineering ontology developed in the scope of the project (Gehre et al, 2000). Thus, the platform is a bridge between information and tools, located anywhere throughout the Internet.

The substantial novelty in the ISTforCE approach is (1) that it provides a personalised human-centred environment, enhancing current, less flexible project-centred approaches, (2) that it promotes the concept of an open collaboration platform where both users, managers and providers of engineering information, services and tools can meet, (3) that it makes flexible and customisable object level data exchange possible and (4) that an infrastructure for on-line e-business can be seamlessly established at all system levels – for legal and financial transactions.

### 3.5 The eLegal project : Specifying Legal Terms of Contract in ICT Environment (IST-1999-20570)

The main aim of eLegal (eLegal, 2001), led by Loughborough University, is to define a framework for specifying legal conditions and contracts to enable a legally admissible (exclusive) use of ICT in project business. In this way, all parties involved in the VEs, including SMEs, will be confident that there is a legal framework regulating their new ways of working leading to more trust and hence, improved business relationships. In order to enable a legally admissible (exclusive) use of ICT in project business, the eLEGAL project will prepare the following main deliverables: user requirements for legal support in construction projects; library of re-usable clauses and model contracts; contract configuration and negotiation tools; simulated contract negotiation game; and recommendations to standardisation bodies. eLEGAL commenced by defining industrial requirements for ICT based legal support, taking the construction industry as a pilot for other industries. It will define the legal basis for contracts on ICT use in the virtual enterprise, accommodating variations for the different participating countries, including the varied contractual arrangements, procurement models and ICT support needs of the European industry (specifically the UK, Finland, Germany and Italy). These variations will also be reflected in the electronic library of clauses that will be built. The dependencies between these clauses and between clauses and ICT solutions will then be established. This will form the knowledge base of the 'contract configuration tools' – software that will be developed in order to produce model contracts for different forms of virtual enterprises in construction projects. Additionally, these contracts can be easily negotiated by using a "virtual negotiation room" on the Internet, in which different parties of the virtual enterprise (working together on a construction project) who want to form an ICT contract, are automatically guided while being linked together via the Internet. This approach will help to accommodate the various factors that influence the application of ICTs to VEs,

such as: client – type and experience; project – size, scope and nature; VE parties – number, location, technological capabilities; etc.

Hence, the main result of eLEGAL will be contract negotiation tools, sold or accessible at a low price level, to improve project business relationships within virtual enterprises in construction projects and which will lead to more trust and reduced number of disputes. eLEGAL will also establish a help desk for enquiries on the use of the developed tools, and re-package them as a simulated contract negotiation game. This will help in education, training and raising awareness on legal aspects of ICT usage within and between virtual enterprises.

### 3.6 The GLOBEMEN Project: Global Engineering and Manufacturing in Enterprise Networks (IST-1999-60002)

The aim of GLOBEMEN (GLOBEMEN, 2001), led by VTT, is to create IT infrastructures and related models, methods and tools to support globally distributed and dynamically networked operations in one-of-a-kind industries. The focus is on inter-enterprise integration and collaboration in the three main facets of global manufacturing: sales and services, inter-enterprise delivery process management, and distributed engineering. It has been advocated that despite their apparent differences, various one-of-a-kind industries can be supported by fundamentally similar kinds of ICT tools (Hannus et al,, 2000). The project aims to find commonalities between various industrial domains and cultural environments and to suggest an integrating reference architecture. Different application systems can be developed based on the generic architecture. The potential is to magnify the global market for ICT solution providers while offering enhanced support to the industry. It has been noted and reported that within dynamic distributed engineering in construction environments, it is necessary to have a usable and commonly accessible infrastructure that can be quickly set-up and configured (Kazi et al, 2001). Furthermore, it is noted that since each participant entity would have its own legacy system, there is a need to both differentiate and maintain what is internal and common (released) information. It is advocated in GLOBEMEN that organisation specific legacy systems could exchange information with each other in a transparent manner through provision of and extraction from a shared distributed engineering environment. The environment would provide repositories for storage of shared and released information in addition to the provision of some common VE specific services. A generic form of a possible distributed engineering environment was developed. This consisted of two main components:

- Distributed Engineering Environment: This constitutes the common data and information repository, and sharing environment for entities participating in the distributed engineering setting. Typical services provided include distributed groupwork and sharing of information based upon available (or agreed upon) standards. Furthermore, depending on the needs of the participants and of the product or service to be delivered, different product model management, document management, and process management were incorporated.
- Distributed Engineering Interface: This constitutes the main interface and front-end through which organisation specific legacy systems would interact with the distributed engineering environment. As such, this interface acts as a communication bridge between the two systems and furthermore, as a control agent for the transfer and management of released information from organisation specific systems to the shared distributed engineering environment.

Further developments in GLOBEMEN will focus on the development of industry specific prototypes that will then be inter-connected through a common VE platform. As such, the complete life cycle covering sales and services, inter-enterprise delivery process management, and distributed engineering will be covered.

## 4. ICCI WORK STRUCTURE

From the above description it is quite obvious that the ICCI clustered projects present not only strong overlapping areas, but also quite interesting complementarities. In order to achieve its ambition, the ICCI project plans to elaborate on the results of each of these projects. Table 1 summarizes the main outputs from each project with a clear objective to harmonize and standardize these results. To that end, the work is organized into six main work packages with a seventh dedicated to the project co-ordination and management.

Workpackage 1 (Industry requirements and needs in the global eBusiness) aims at reviewing and synthesising, but more importantly consolidating and validating at a European level, the requirements in relation to the use and deployment of ICT in construction. This workpackage is led by University of Desden.

Workpackage 2 (ICT infrastructures for construction projects) will provide an up-to-date state of the art ICT review in the area along with an assessment of potential risks regarding the construction industry acceptance and take-up of these identified techniques. This workpackage is led by University of Ljubljana.

Worpackage 3 (Human and organisational aspects for ICT in construction) is a key component of the ICCI project. This workpackage is led by University of Salford. Its main objectives are:

- To address and examine human and organizational issues related to the development of the construction sector and formulate critical success factors for the future of the sector.
- To collect and synthesize results and information regarding training needs of construction employees.
- To collect best practice from member projects and prepare a consolidated guide in order to enable construction companies to formulate a business strategy incorporating new technological capabilities, to re-engineer the processes to support new functionalities and improve performance and to manage successfully the organizational change.

Workpackage 4 (Legal and Contractual Aspects of Networked Co-operation in Construction) will capture the legal issues associated with the use of ICT as the prime means of networked co-operation in construction. This workpackage is led by Loughborough University. The main objectives are:

- To assess the latest developments in the area of legal and contractual support for the use of ICT in construction.
- To review the technologies developed within the cluster projects to identify gaps and potential problems (for example legal responsibilities of information and documentation derived from objects or derived from conversion software based on data exchange standards).
- To integrate the legal and contractual aspects of ICT in construction into the proposed "ICCI IT services platform".
- To provide recommendations and criteria for the integration of legal and contractual aspects in future developments of ICT tools.

Workpackage 5 (Dissemination and Awareness) will ensure the continuous dissemination and wide industry acceptance and adoption of the ICCI results. This workpackage is led by VTT.

Workpackage 6 (Integration, strategy and future plans for IT in construction) aims at integrating and consolidating the conclusions from the whole project into an overall strategy and roadmap, allowing a continuous identification of gaps in RTD, refining the joint strategy to be followed in order to reach the ICCI objectives, providing suggestions and ideas for potential new activities and projects, and delivering (to ICCI members, the EC and the construction industry) useful arguments in justification

of future research needs and future developments for the European Research in the area of IT in Construction. This workpackage is led by TNO.

| Methods, Models, Tools, Technologies | OSMOS | eConstruct | Divercity | ISTforCE | eLEGAL | GLOBEMEN |
|---|---|---|---|---|---|---|
| Internet-based services for team work | ■ | | | ■ | | ■ |
| Information sharing and exchange | ■ | ■ | ■ | ■ | | ■ |
| Social, Human and Cultural aspects of eWork | ■ | | | | | |
| Virtual Reality | | | ■ | | | |
| Distributed Workspaces | ■ | | ■ | | | ■ |
| Legal Aspects | ■ | | | | ■ | |
| Enterprise modelling, engineering and management | ■ | | | ■ | | ■ |
| Security, digital signatures, etc. | ■ | | | | ■ | |
| Project portals and work spaces | ■ | | | ■ | | |
| eCommerce & inter-enterprises eBusiness | | ■ | | | | |

Table 1: Main contributions from each project forming the ICCI cluster.

## 5. CONCLUSIONS

The ICCI project subscribes to the programme's aims and vision of a globally networked economy that enables European construction companies (in particular SMEs) to increase their competitiveness in the global marketplace and improve the processes leading to Building products. It also aims at providing the flexibility to be free from many of the existing constraints imposed by the nature of the construction industry. It is the role of the European RTD and the objective of ICCI to pave the way in helping companies to achieve this vision. In that respect, it is expected that the ICCI initiative will create and foster international collaboration between selected funded projects (and other new projects as well, through dedicated workshops, potential participation to the ICCI board, etc.) around the theme of "networked co-operation in the construction industry", and provide the glue that reinforces the complementarities between them and the synergies derived from their work, by:

- Promoting the use and efficient deployment of ICTs to contribute to a highly competitive European Construction networked economy.
- Allowing the establishment of a platform from which novel management as well as technological ideas can emerge and contribute to European policy development in various areas of construction and related industries;
- Reinforcing collaboration with Standardisation bodies to ensure coherence in European technology deployment and in creation of a new open framework for fair competition and fast innovation.

The project results will be made available through the project web site (http://icci.vtt.fi).

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