INTER-ENTERPRISE INFORMATION MANAGEMENT IN DYNAMIC VIRTUAL ENVIRONMENTS: THE OSMOS APPROACH

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ABSTRACT: The paper gives a comprehensive description of the OSMOS[1] project. OSMOS aims at providing an infrastructure that brings together, and promote co-operation between actors and companies regardless of their size and location. In particular, an emphasis is put on developing an information infrastructure, including low entry level tools (cheap and user-friendly) that will enable SMEs to be more closely integrated on construction projects, and that will allow them to take a more active part in the design and delivery of the construction product. First, the paper gives a general overview of the construction industry process and organisational settings along with their associated limitations, and introduces the aims and objectives of the OSMOS project. Following this introduction, current as well as past research in the area tackled by the OSMOS project are presented. An emphasis is put on results and findings that can be potentially exploited. The OSMOS solution is then described via a generic system architecture addressing the information sharing and process control requirements of the project. Finally, the paper presents the anticipated results of the project along with the technical, process, and business ingredients for a successful implementation and take-up of the resulting internet-based service prototypes.

KEYWORDS: Computer Integrated Construction, Virtual Enterprises, Internet.

1. INTRODUCTION

The Building and Construction domain has always been referred to as a traditional industry, despite the fact that it has adopted for decades the modus operandi of the so-called Virtual Enterprise (VE). In fact, buildings have long been designed and constructed by non co-located teams of separate firms who come together for a specific project and may never work together again. Organisations and individuals participating in a team bring their own unique skills,

[1] OSMOS is a European R&D project within framework V: IST-1999-10491, *Open System for inter-enterprise information Management in dynamic virtual envirOnmentS*. The consortium includes construction IT service providers: *DERBi*, *JM Byggands*, *Olof Granlund*, and European leading research centres and academic: *CSTB*, *Information Systems Institute* of University of Salford, *VTT*.

knowledge and resources, which include proprietary and commercial software applications (Fig.1). Recent surveys [Zarli et al. 1998; Vakola et al. 1999] reveal that current technology solutions in use in the building and construction domain present one or more of the following characteristics:

- *Extensibility:* despite recent evolutions, mainly due to the impact of the Internet, existing solutions are still often fixed and not open, with a lack of support for legacy, as well as new, upcoming systems in terms of hardware, software, databases, and networks.
- *High Entry Level:* IT solutions are still often expensive to buy for SMEs, as reported by the OSMOS end-users. More entry levels should be provided, e.g. from personal (low cost) to enterprise (high cost) editions.
- *Lack of Scalability:* most available proprietary and commercial solutions offer limited growth path in terms of hardware and software.
- *Application Centric and lack of support for business processes:* there is often a requirement to organise the enterprise around the adopted IT solution.

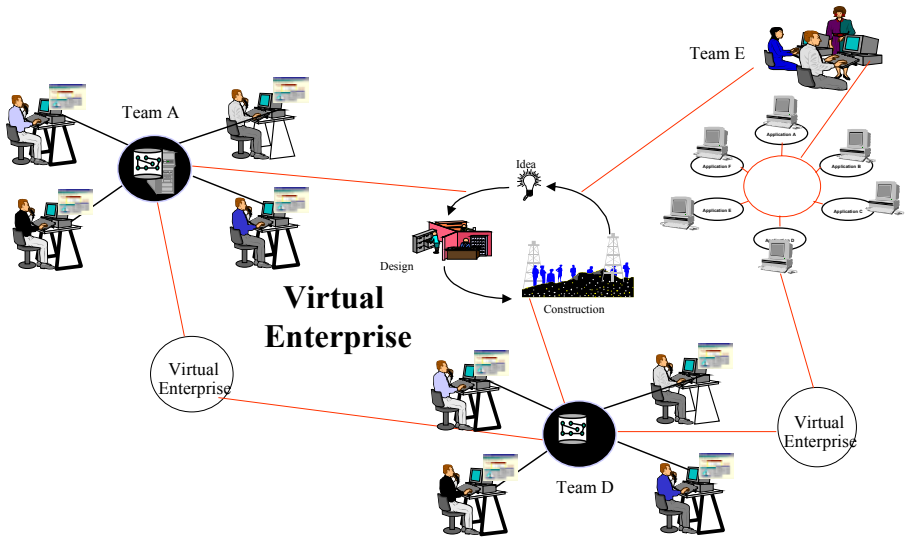

Figure 1. Construction Industry Context

Due to this context, various problems have been identified. These include the following:

- IT support for the fragmentation imposed by the very nature of the industry in terms of communication and information exchange still needs improving.
- Interactions between actors are still not well co-ordinated, especially because of the inherent dynamic business relationships taking place in the construction industry. Commercial workflow systems didn't have the expected impact on projects, and within companies, mainly because of the characteristics mentioned above.
- IT support for Information and document management varies from one company to another, but overall is still done in a traditional and ad hoc way.
- Project documents present a great deal of redundancy and often lack structuring.

This overall context has often resulted in information inconsistencies, business process inefficiencies, and change control and regulatory compliance problems.

The overall aim of the OSMOS project is to enhance the capabilities of construction enterprises, including SMEs, to act and collaborate effectively on projects by setting up and promoting value-added Internet-based flexible services that support team work in the dynamic networks of the European construction industry. This aim translates into the Scientific and Technological measurable objectives described below:

- Specify Internet-based services for collaboration between dissimilar construction applications and semantic cross-referencing between the information they manipulate.
- Specify Internet-based services allowing the co-ordination of interactions between individuals and teams in a dynamic construction virtual enterprise.
- Specify a model-based environment where the release of, and access to, any shared information (including documents) produced by actors participating in projects is secure, tracked, and managed transparently (in real time whenever possible, otherwise asynchronously).
- Provide low entry level tools (cheap and user-friendly) to small enterprises to act and participate in construction virtual enterprises.
- Allow end-users to use their proprietary and commercial applications on projects, by implementing the specified services (e.g. via plug-ins), and allow them to transparently participate to collaborative work in dynamic virtual enterprises.
- Implement the model-based environment providing a distributed information management support for the virtual enterprise.
- Set up two OSMOS Internet-based team work service providers prototypes for the purpose of the project, and ensure their take-up, as commercial offers, after the completion of the project.
- Define the migration path to using the OSMOS approach.
- Analyse the likely benefits of adopting the OSMOS approach.

The paper gives a comprehensive overview of the OSMOS proposed solution. A generic system architecture is presented along with its technology constituents in terms of services, tools, and middleware supporting the construction virtual enterprise. This architecture is in the process of being deployed and interpreted within two of the three end-users involved in the project, to set up internet-based team work services. It is worth mentioning that the research is being conducted through three iterations. Each iteration has a duration of nine months, and will be used to assess and validate the OSMOS infrastructure, and address the potential risks in relation to the implementation of the proposed solutions. The important aspect is that change is anticipated at any stage of the software product lifecycle. In addition, potential risks are identified and prioritised early in the lifecycle, and are at the core of each iteration leading to the final OSMOS solution.

2. COMPUTER INTEGRATED CONSTRUCTION BACKGROUND AND STATE OF THE ART

Advances in personal computer technology along with the rapid evolution of Graphical User Interfaces, networking, and communications have had a substantial impact on industry business processes. The emergence of Client / Server applications (ranging from file server to database server applications), at the end of the 80s, have offered a first promising answer to the problems of flexibility, scalability (ability to upgrade a system without having to re-design it), and extensibility (ability to extend the underlying data structures of applications without loosing the data) of modern businesses. Software applications were being downsized from

expensive mainframes to networked personal computers and workstations that are often more user-friendly and cost effective. The introduction of the Internet along with advances in Three-Tier architectures and Middleware technologies have brought new challenges and competitive advantages that the industry is now trying to comprehend and exploit. On the other hand, new techniques have been developed to integrate legacy and proprietary systems with new upcoming component based applications. These legacy, proprietary and commercial applications widely used by the industry range from low cost document management systems to high cost groupware applications.

State of the art research in the application of IT in construction reveals that integration has been achieved, mostly, on static models that define the structure of shared information in the form of files or databases. The OSMOS research team advocates that integration should be made through frameworks which define semantic relationships between the interfaces of separate distributed components. This is an area where Construction needs advances. Such frameworks are already under development, especially within the Object Management Group through business object facilities, based on the Common Object Request Broker Architecture [OMG 1996]. On the other hand, the World Wide Web has now emerged as a result of the growth of the Internet. It was, until the advent of HTML, mainly used in academia. However, HTML (which was derived from SGML), is mainly used to describe and exchange information contents as opposed to semantics. The recent XML (eXtensible Markup Language), and the related DOM (Document Object Model) standards combined with semantic object models describing a building, e.g. STEP [STEP 1994] and IAI-IFCs [IAI 1997], offer a unique opportunity to promote effective information sharing in the VE.

However, the success of collaborative work relies not only on the ability to provide solutions to the problems of multi-criteria information representation, information sharing and exchange, information life-cycle support; but, also, the support of the various interactions taking place between individuals / groups / or corporations as well as the management of their authorities and rights over information in accordance with their precise roles in the VE. These important issues are tackled within the field of computer support for co-operative work (CSCW). CSCW is more generally concerned with the introduction and use of groupware systems to enable and support team work. Groupware solutions include traditionally a subset of the following system components: Workflow (task scheduling), Multimedia Document Management, E-mail, Conferencing, and shared schedule of appointments. A recent survey of groupware constituent technologies [Rezgui et al. 1999] reveal a lack of homogeneity, and a diversity of applicable de facto standards and APIs from the leading Groupware vendors. In fact, the last decade has seen a tremendous activity in new specifications and developments of standards and architectures for CSCW and enterprise application integration. While these developments seem to offer a challenging opportunity for the VE, they do hide complex architectural problems in relation to the selection of the right tools, toolboxes and infrastructures.

Therefore, a suitable team work IT-based solution requires a broad methodological approach, a deep understanding of the information / process requirements, and also the understanding of the dynamics and the specificity of the context in which the support for team work is required, namely the Construction industry.

3. THE CONSTRUCTION VIRTUAL ENTERPRISE REQUIREMENTS CAPTURE

The work involved in the requirement capture phase consists of, first, the analysis of intra-company business processes, and information management practices taking place within the project end-users (Derbi, Granlund and JM). In addition, the type and nature of inter-company interactions taking place on multi-disciplinary construction projects are being analysed along with the nature and semantics of the information being produced and exchanged, with a strong emphasis on contractual, legal and IPR (Intellectual Property Rights) aspects underlying this collaboration. Finally, the set of tools commonly used on projects are identified, with an emphasis on the understanding of their API (Application Programming Interfaces), communication mechanisms, and their information requirements. Based on the above analysis, generic models are now being developed to describe basic processes taking place in a Construction VE.

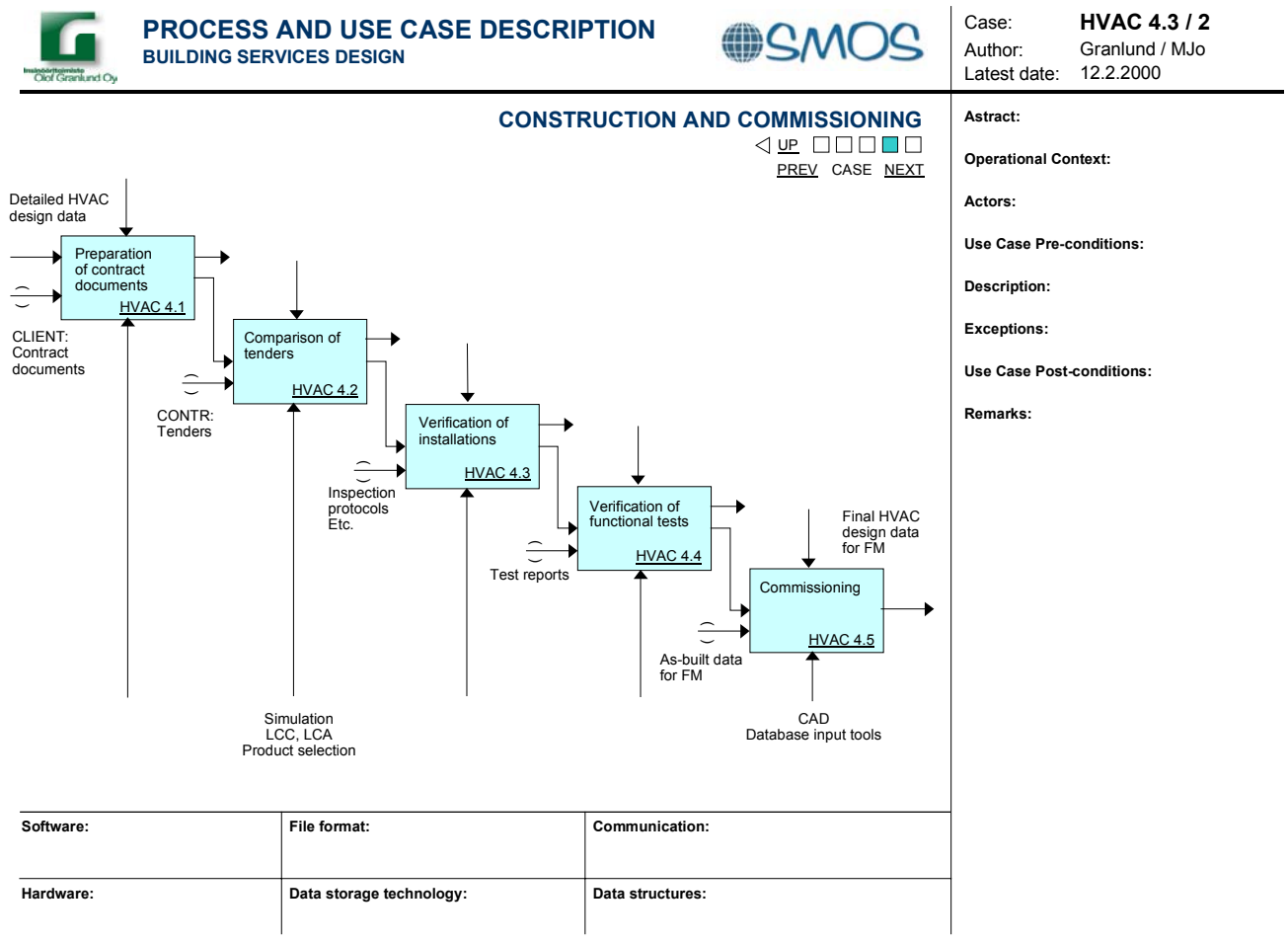

Figure 2. Granlund Process and Use Case Description in the Building Services Area.

Two complementary approaches are used to comprehend the end-users business processes, and help to capture the requirements of the OSMOS system. IDEF0 is used to define high level process activity models describing the business processes and information management practices taking place in the building process, within the OSMOS end-users companies, and also between partners on a construction project, i.e. at level of inter-companies communication (Figure 1). A set of Use Cases (Unified Software Development Process, from

Jacobson, Booch, and Rumbaugh), at a lower level, are specified to detail the different ways in which the OSMOS system is to be used (Fig.3).

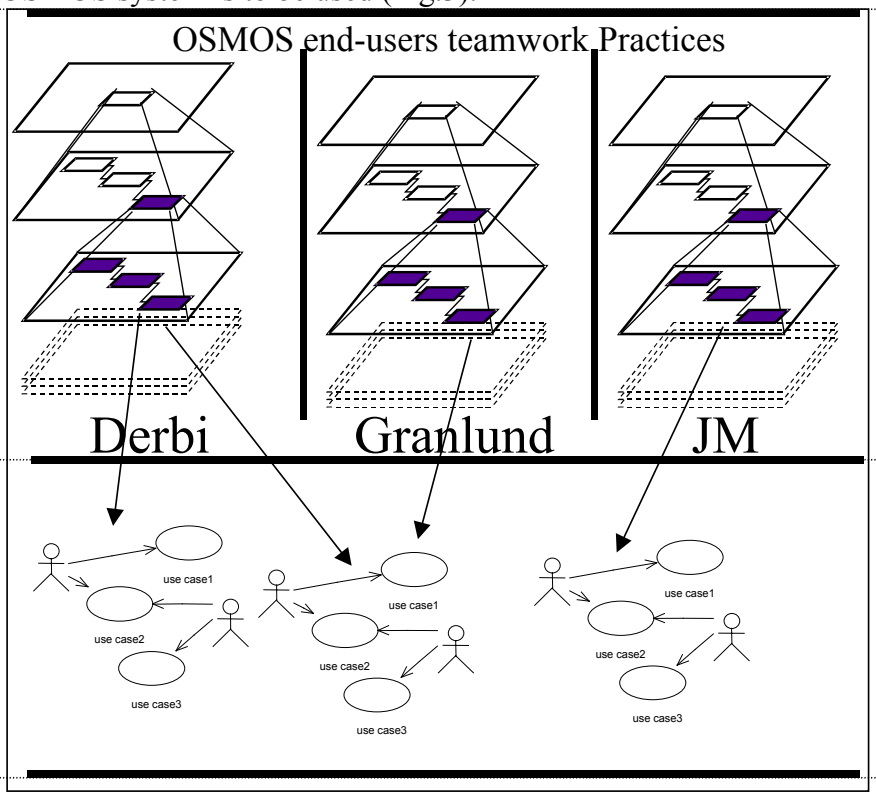

Figure 3. Combination of IDEF0 and Use Case Approach for OSMOS Requirements Capture.

In order to facilitate the description of the Use Cases, templates have been designed and proposed for both Use Case, and software / hardware description. A use case is a sequence of actions performed by the system, which normally corresponds to a business transaction and produces a tangible result. The following elements are expected to be provided by the end-users for each identified Use Case:

- *Use Case*: name and number.
- *Author*: name.
- *Creation or last update Date.*
- *Abstract*: short description of the objectives of the Use Case.
- *Operational Context*: this part explains the specific context in which the Use Case is supposed to be applied as well as the potential constraints (at least those known at that step of the formalisation process) like: frequency of application of the Use Case, input/output data (this can be linked to some initialisation of parameters that are internal to the system), possible concurrent operations, availability of data (i.e. data that exist and are available, or not available when the Use Case is triggered, or totally unknown, etc.), confidentiality, friendliness of the user interface, etc.
- *Actors:* identification of all actors (at least one) involved in the Use Case.
- *Use Case Pre-conditions*: they describe the functional prerequisites, such as initialisation conditions, use restrictions, etc.
- *Description:* it may include the following information (the list is not restrictive):
    - The trigging event.

    - The sequence of interactions and information exchanges between the system and the actors.
    - The identification of data that are handled, modified, recorded, etc.
    - The possible iterations (repetitions) and the rules of selection (*if ... then ...*).
    - The events (messages) sent to actors; etc.
- *Exceptions:* this part describes the anomalies that can occur during the process.
- *Use Case Post-conditions:* they describe the possible constraints put on the system at the end of the Use Case. It should be noted that pre-conditions and post-conditions provide a way to understand (and check) the sequence of Use Cases.

The requirements capture is still ongoing (at the time of writing the paper). A full report on the requirement capture stage will be described in a later publication.

4. THE OSMOS SYSTEM ARCHITECTURE

Recent and continuous investigations on the use of advanced computer-based technologies, especially in ESPRIT funded European projects, including VEGA [Stephens et al. 1999], CONDOR [Rezgui et al. 1998], ELSEWISE [Elsewise 1999] and GENIAL [Radeke et al. 1999], have shown promising results. The today difficulties lie in identifying the right reference marks and methodology to relate user requirements and needs to the adequate technology. This chapter proposes a first investigation towards an approach to solving these issues, by establishing a common foundation to better take advantage of the benefits of distribution and Internet-oriented technologies. In addition, one of the major tasks of the OSMOS project is to review recent or emerging information and communication technologies as well as team work services, related to communication (including middleware), co-operation (including standardised shared information repositories), co-ordination (including task synchronisation, and access control), and documentation (including document routing, and version control). Available commercial offerings from the main vendors are being analysed, along with their underlying technology. An assessment of the potential risks regarding the construction industry acceptance and take-up of the identified Information and Communication Technologies will be conducted in conjunction with the OSMOS end users.

Figure 4 introduces a generic functional architecture of the OSMOS project supporting co-operation between a variety of commonly used applications in a Construction VE. In particular, the OSMOS Integration services will provide means by which proprietary and commercial building and construction applications can inter-work by enabling the sharing and cross-referencing of information. This will be based on existing standards, including CORBA [Frankel 1999] services, the (XML) DOM object API (W3C), and existing leading groupware vendors APIs. However, it is worth pointing out that the above APIs and services will not all be implemented. The OSMOS project will, rather, identify, extend whenever appropriate, and specify a subset of the above that are suited and adapted to the specific business and information requirements of the VE in the Building and Construction domain.

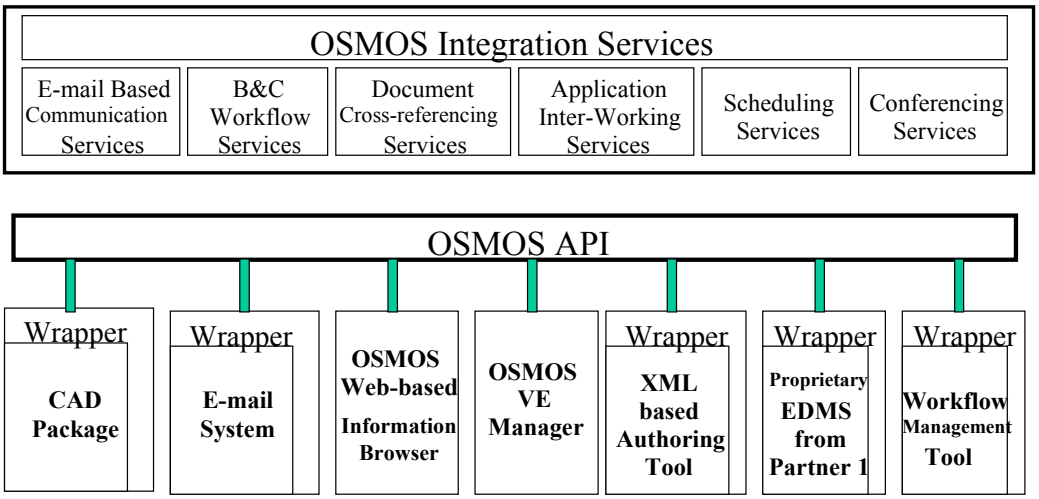

Figure 4. The OSMOS Functional Architecture.

In addition, an OSMOS VE manager will be developed. The latter will provide advanced functionality for team work service providers to manage the VE. As mentioned earlier in the paper, the implementation phase will undergo three incremental iterations. The scope of each iteration is as follows:

- Iteration 1: this will produce a mock-up implementation of the OSMOS infrastructure. A first version of a rudimentary *OSMOS VE Manager* will be produced. The latter is intended to implement part of the OSMOS services, and will also be used as a low entry level tool by SMEs.
- Iteration 2: this will produce a working system that simulates a virtual enterprise in which the project end-users participate via their OSMOS compliant applications. These applications will implement part of the OSMOS Integration services, including the OSMOS inter-working services. New services will be implemented on the *OSMOS VE Manager* allowing the management of the OSMOS VE.
- Iteration 3: this will produce the final and workable OSMOS system.

XML will play a major role in the implementation of the OSMOS construction virtual enterprise. XML, that originates from SGML [SGML 1986], can be viewed as a standard way of passing data between many heterogeneous distributed application servers, as well as across multiple operating systems, therefore as a *basic model for data exchange at level of middleware layer*. It can be considered as a protocol offering in some cases an alternative to COM and CORBA protocols, especially in the Internet context (one can keep on using classical HTTP firewalls, without having to open those firewalls to DCOM or IIOP through proxies), thus facilitating distributed computing on the Internet. Even more, it could be considered as a link for communication between a COM domain and a CORBA domain, therefore using XML as a way of bridging protocols.

XML can be used to define the container for a message content, for any type of data provided by a repository. For example, considering two MOMs (Message Oriented Middleware) that are used within a project, it is possible to establish an XML grammar to encapsulate any message, thereby allowing to distribute the same message through both middleware environments, provided that there is a process written for each environment that is able to

extract the route and content of the message. Thus, XML supports *data portability* as a platform-neutral document description meta-language that offers means for data serialisation. It is worth noticing, at that point, that it can be quite beneficial to associate XML with Java, which offers *code portability*, as supporting the development of platform-neutral applications. Some of the expected benefits are:

- XML appears to promptly become a standard, with a potential role as a universally accepted format for the exchange of information between heterogeneous applications. XML is expected as one of the primary means for developers to design multi-tier applications in heterogeneous environments.
- XML seems to be appropriate in co-operative applications because dealing with documents and means to convey business knowledge. An interesting perspective is to define and use meta-data (this currently is few or not existing in most applications) that can be exposed through XML messages.
- XML supplies cost-effectiveness for implementing Internet and distributed applications based on XML software tools and components (both on client and server sides). As regards the software market, a lot of actors (IBM, Oracle, Sun, etc..) integrate the parsing and generation of XML documents within their platforms. A lot of application servers use the XML format for sending information, and databases integrate as well an XML parser. In addition, a bunch of freeware tools are accessible through the Web. Thus, as soon as an application is powered with XML, this should lead to minimal effort to exchange information.
- XML provides a way of tagging data and objects as they are called for on a network. Extending this feature already identified on the client side, allows an automatic way of populating databases on the fly with XML (especially local databases for specific applications connected to Intra/Extranet). Besides, in order to deal with the semantics of data that compose the content of XML messages, current efforts are undertaken, among others in the W3C (World Wide Web Consortium), to define more semantics attached to an XML document content, including element names and rich data types.

The consortium has started the specification of the functionality of the OSMOS architecture. A first prototype implementation of the OSMOS VE Manager and the OSMOS web-based document management system will be available in a very near future. These will be deployed through two field trials that will be conducted in France and Finland. The field trials will be evaluated and will be followed by business recommendations regarding the deployment of the proposed technologies.

5. CONCLUSION

The paper presented the European OSMOS project. The latter involves leading research and academic institutions, along with key industrial players, in the building and construction domain. The OSMOS system architecture was described along with a set of base technology that are potential candidates for OSMOS. The services that OSMOS will provide are expected to enable construction industry software to be integrated with traditional Groupware software components, and, on the other hand, to accommodate intra-company and inter-company communication. It is expected that the project will advance the state of the art in the application of CSCW in the construction domain by:

- Providing construction specific, and scalable solutions, that take into account the particular organisational settings of each construction enterprise participating in the VE, including SMEs.
- Providing IT and organisational solutions that promote trust and social cohesion among the partners of a construction VE.
- Providing effective, model-based solutions, to support Communication, Co-operation, and Co-ordination between individuals and groups collaborating in a construction VE, based on the specificity and information / process requirements of the Construction domain.
- Providing models for business processes, working methods, organisation, contracts, and legal responsibilities related to CSCW in a VE.

One of the fundamental tangible objective of the OSMOS project is the ability to deploy a flexible adapted team work solution in a limited amount of time, e.g. in days or few weeks as opposed to months, as it is the case today for the deployment of Electronic Document Management (EDM) and Product Data Management (PDM) systems in construction companies. The project end-users are presently involved with the deployment and interpretation of the proposed system architecture within their organisation, to set up internet-based team work services. The OSMOS consortium is in the process of setting up four user interest groups in Finland, France, Sweden and the UK. These groups are expected to provide ways of translating the results to other industrial sectors across Europe.

6. ACKNOWLEDGMENTS

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