A COMPREHENSIVE DESCRIPTION OF THE HUMAN, PROCESS AND TECHNICAL REQUIREMENTS OF A CONSTRUCTION VIRTUAL ENTERPRISE: THE OSMOS PROJECT

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ABSTRACT

The paper introduces the aims and objectives of the European OSMOS[1] project. After a brief description of the requirement capture process as well as the presentation of a proposed high-level Generalised Process Model that describes the process of setting up, maintaining and dismantling a Virtual Enterprise, the paper presents, using the Unified Modelling Language (UML), how each process activity is carried out. The paper then discusses how useful the Use Cases and Sequence Diagrams presented in this section are, when both Conceptual Models and technical designs are produced. Finally, a comprehensive description of the proposed OSMOS infrastructure is given. The project is ongoing and supported by four user interest groups in Finland, France, and Sweden. These will provide ways of validating and translating the results to other industrial sectors.

Keywords: Virtual Enterprise, OSMOS, CSCW, Analysis, Design, Construction, Model, UML

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, knowledge and resources, which include proprietary and commercial software applications. Recent surveys [1] 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.

[1] OSMOS (http://cic.vtt.fi/projects/osmos/index.html) 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 three Construction IT service providers: *DERBi, JM and Olof Granlund,* and three leading European research and academic institutions: *CSTB, VTT and the Information Systems Institute* of the University of Salford.

- 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.

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 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 VE.
- 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 VEs.
- 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 VEs.
- Implement the model-based environment providing a distributed information management support for the VE.
- 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 VE. 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 teamwork services.

METHODOLOGY

The methodology that has been used within OSMOS can be summarised as follows: starting from specific models as defined by the project end-users (DERBi, Granlund and JM), a Generic Virtual Enterprise Process Model (GVEPM) has been developed [2], with two main sections: *Establish and Maintain a Virtual Enterprise* (VE Generic) and *Deliver and Maintain a Product* (Construction specific).

From careful analysis of the GVEPM, a set of Use Cases has been defined using the Unified Modelling Language (UML). These describe how the OSMOS system could potentially be used *at a business level* (e.g. "Manage Information Elements"). Each Use Case has then been broken down into a set of UML Sequence Diagrams which describe *how* the Use Case can be performed. This also includes a detailed description of how the users and systems external to the OSMOS system (both of these are known as *actors* within UML) take part in the process, the internal components of the OSMOS system, and how the components interact with each other and the actors. In parallel to this work, a set of Conceptual Models is produced (also using UML) to allow the members of the OSMOS Consortium to properly communicate and discuss their requirements with each other. Following a number of iterations where the Sequence Diagrams and Conceptual Models are analysed and made compatiable with each other, a careful analysis of these allows the production of an internal (technical) design of the OSMOS infrastructure to be undertaken. This is derived through the analysis of the internal components and their interactions with each other, which then lead to the abstraction of actual classes, attributes and methods. A brief overview of the aforementioned Use Cases, Sequence Diagrams and Conceptual Models is given in the following sections.

THE OSMOS USE CASES

The Use Cases define, at a business level, *how* the OSMOS Architecture could be used when implemented.

Figure 1 displays the Use Cases at the top level. The reader will notice that there are three packages that mirror the activities specified in the GVEPM:

I. Set Up The Virtual Enterprise
II. Manage The Virtual Enterprise
III. Dissolve The Virtual Enterprise

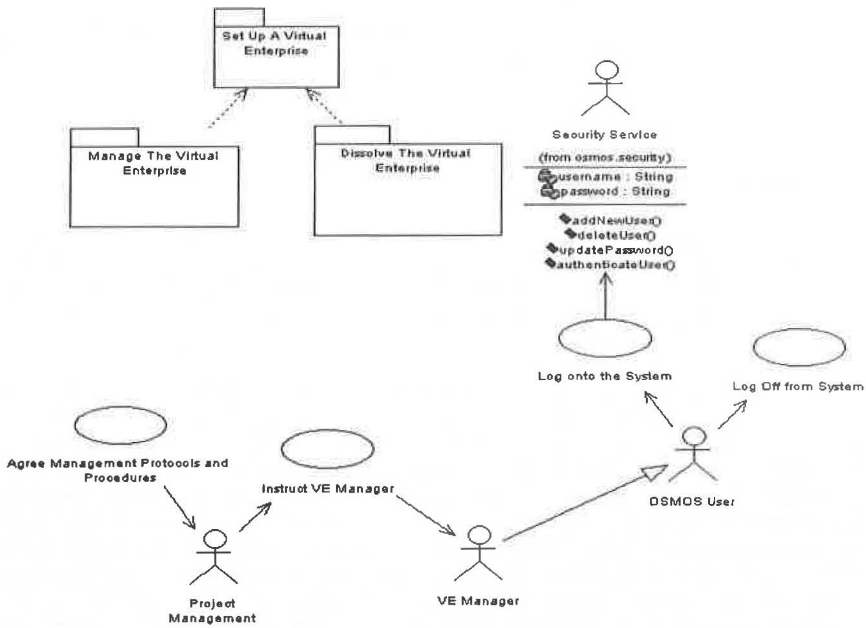

Figure 1: OSMOS Use Cases

Figure 1 is fairly self-explanatory. *Agree Management Protocols and Procedures* and *Instruct VE Manager* are both Use Cases that need to take place, but they are business processes that planned not to be supported by the OSMOS system. The remaining Use Cases, *Log onto the System* and *Log Off from the System* are applicable in all cases, and as their names suggest, deal with authentication of users when accessing the OSMOS architecture. The relevant actors are as follows:

I. A *Project Management Committee* is the person (or group of people) in charge of managing the project;

II. A *VE Manager* is described as the person who is in charge of administering the VE, in the same way that a Database Administrator is in charge of administering a Database and its corresponding management systems;

III. A *VE Manager* is also an *OSMOS User*: someone who uses the OSMOS Architecture;

IV. and the *Security Service* is an external system that provides security and authentication services to the OSMOS Architecture.

In a similar way, Figure 2 shows the contents of the *Manage The Virtual Enterprise* package. The reader will realise that the Use Cases presented herein are at a relatively high "business" level, and in fact in a number of instances each of the Use Cases may be broken down into a number of separate Use Cases, at a finer level of granularity. This is in fact the approach that has been taken by the OSMOS Consortium. By way of an example, the *Communicate With Participants in the VE* Use Case (in figure 2) has, so far, been broken down into four separate Use Cases: *Locate Participant, Get Email Address, Import Address Book* and *Send Message.*

In fact, there are a large number of sub-Use Cases which can be derived from the Use Cases presented above. However, because the OSMOS Project is using an incremental and iterative development methodology, the analysis and discovery of such sub-Use Cases has been initially restricted to a small set of cases for the first iteration of the project.

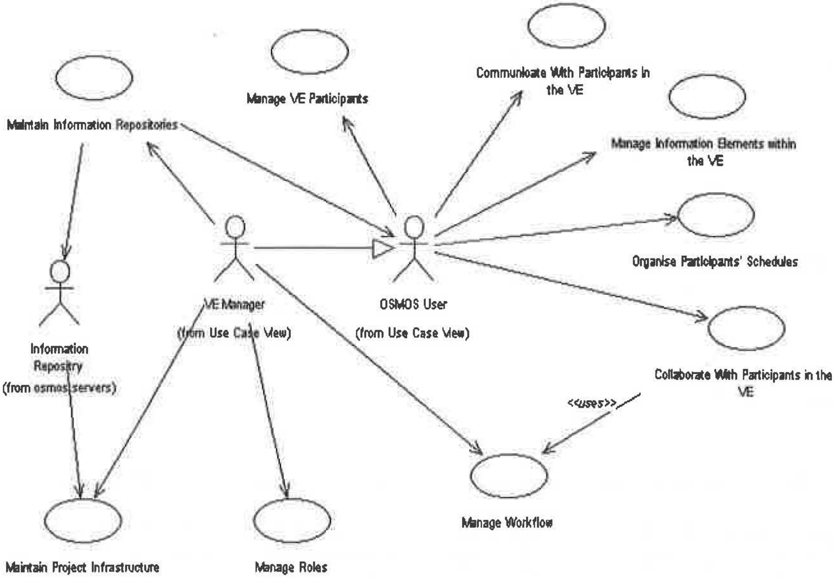

Figure 2: Manage The Virtual Enterprise

THE OSMOS SEQUENCE DIAGRAMS

The OSMOS Sequence Diagrams detail, in UML and at a fine level of granularity, *how* each of the derived ("sub") Use Cases would actually be carried out by objects within the OSMOS Architecture. For each individual ("sub") Use Case, a Sequence Diagram has been produced. They detail which objects would be required, what messages are passed between them (at a later stage, these messages are used to determine which objects call which methods of which of the other objects, and in what order) and how these objects interact with external actors (such as Users or external systems.) Each Sequence Diagram can be quite complex in nature, and can also run to over two A4 pages in length. It is worth mentioning that over 45 Sequence Diagrams have been produced within this first iteration. However, to aid readability and comprehension of the methodology, the Sequence Diagram belonging to one of the above-mentioned Use Cases has been included in this paper. This is to give the reader an appreciation of how Sequence Diagrams fit into the overall methodology employed within OSMOS.

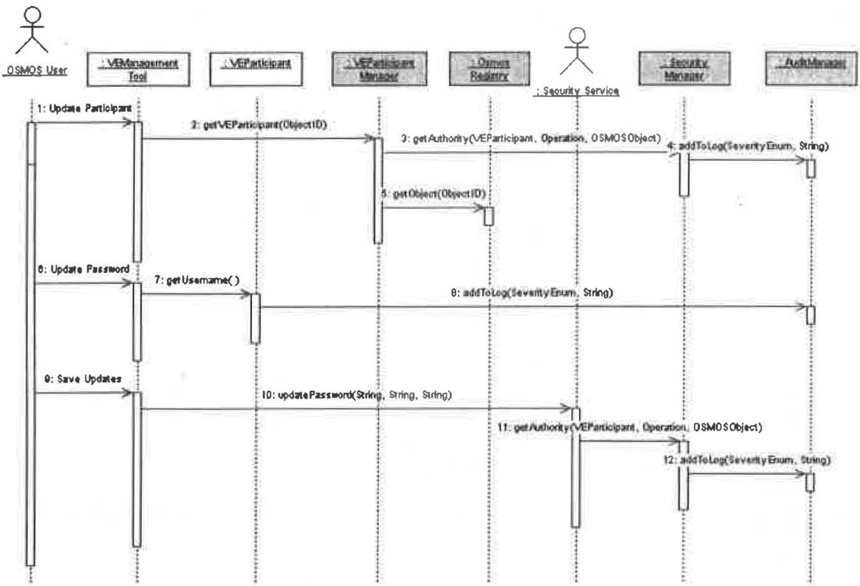

Figure 3: Sequence Diagram for the "Update VE Participant's Password" Use Case

Figure 3 shows the Sequence Diagram for the Use Case entitled *Update VE Participant's Password*. In the initial version of this diagram, the messages sent between objects and actors were written in plain English. However, this version of the diagram shows those same messages, but in a syntax more suited to a technical implementation. Each of these messages is fully documented within the CASE tool that is used to produce these Sequence Diagrams. Those icons denoted by stickmen are Actors (users or external systems) whereas those within a square box are Objects within the OSMOS Architecture.

THE OSMOS CONCEPTUAL MODELS

In parallel to the analysis of Use Cases and production of Sequence Diagrams, the Consortium also started work on a set of Conceptual Models. The purpose of these models, which are also presented using the UML, is to conceptualise the problem domain and present it in an unambiguous form that can be used by the Consortium to agree on a common understanding of how it may be realised. It was felt to be important that this conceptualisation was undertaken without reference to any specific implementation issues (such as technologies and architectures used to implement the model) and without prejudice to any particular perspective or viewpoint. These models have been developed by conducting careful analysis of the Sequence Diagrams produced within the OSMOS project as well as similar models produced in previous projects such as COMMIT [3] and CONDOR [4]. The Consortium discovered that the approach of producing these models in parallel with the Sequence Diagrams was an interesting one. A number of questions were raised in the Sequence Diagrams that were answered by working on the Conceptual Models, and vice versa. Consequently this process was repeated a number of times, using an incremental and iterative process. It was felt that this gave enormous benefits such as increased stability, validity and levels of synergy within the presented results. The OSMOS models currently include the OSMOS Distributed Object Management Model and the OSMOS Semantic Multimedia Document Model.

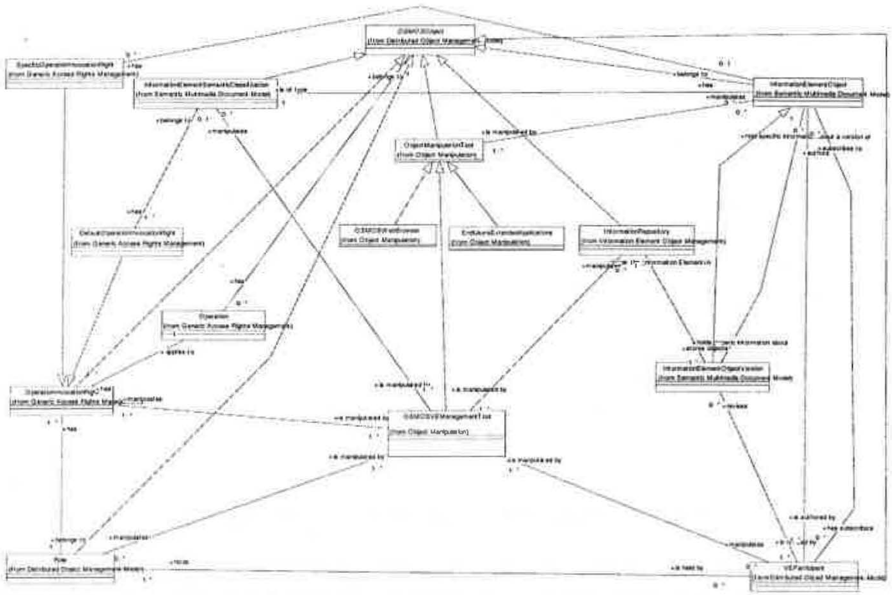

Figure 4: The OSMOS Distributed Object Management Model

The OSMOS Distributed Object Management Model is concerned with the management of released information produced within projects by actors and applications throughout the project lifecycle. The model will eventually address four primary issues that are central to distributed information management, these are: ownership / rights / responsibilities, versioning of information, tracking of dependencies between pieces of information, and change notification and propagation. In addition, the model will tackle various aspects relevant to OSMOS, including contractual (e.g. in case of a dispute the availability of potential digital evidence against an actor must be available without the consent of the same actor), legal (secure continuous availability of all released project information under conditions such as bankruptcy), and IPR issues. As previously noted, not all of the above-mentioned points are tackled in the first iteration of the project.

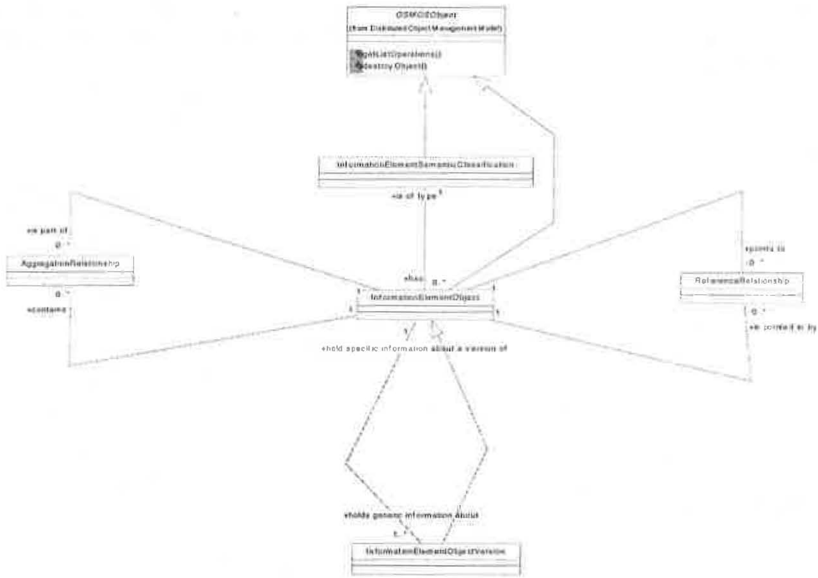

Figure 5: The OSMOS Semantic Multimedia Document Model

The OSMOS Semantic Multimedia Document Model provides ways of handling multimedia documents at the desired level of granularity to enable information / document structuring, and semantic cross-referencing. The OSMOS Semantic Multimedia Document Model in Figure 5 shows how objects produced by the participants of the VEs (such as IFC objects, CAD drawings, documents, etc) are handled within the VE. An object (InformationElementObject) is said to have an 'Aggregation Relationship' when it contains, or is part of, another object (InformationElementObject). Although this could have been shown by indicating a direct association or aggregation relationship in UML, using this method means that it would have been impossible to show how the semantics behind this relationship would be captured in the model. The ability to capture the semantics behind an aggregation relationship is vital to allow the user to state, if applicable, how the first InformationElementObject is related to the second InformationElementObject. This implicit knowledge, if not explicitly stated, can be lost when the document is read at a later date by a user who wasn't closely involved in the creation of these objects. In a similar way, there is also the notion of a 'Reference Relationship'. Such a relationship comes into play when one object (*InformationElementObjec*t) needs to refer to another. Again, although this could have been shown via a direct Association relationship in UML, using this method means that it would have been impossible to show how the semantics behind this relationship would be captured. The implicit knowledge that can be captured and stored about this relationship is again of tremendous potential value to aid the understanding of users, especially if they are new to the VE. The ability to capture the semantics behind this relationship is vital to allow the user to state, if applicable, *how and why* the first *InformationElementObject* is related to the second *InformationElementObject*. One example of such a relationship could be a reference relationship between a document and a spreadsheet. The semantics that need to be captured about this relationship would be something like '*This document refers to financial* *data, this is available in: xyz'* In addition, as the *InformationElementObjectVersion* object inherits from the *InformationElementObject* version, then it is perfectly acceptable for an object to refer to a specific version of an Information Element if this is required.

OSMOS SYSTEM ARCHITECTURE

The proposed architecture of the OSMOS System is presented in Figure 6, based upon the commonly accepted three-tiered architecture. Each layer would use the services of its "lower" layer by making calls to an API.

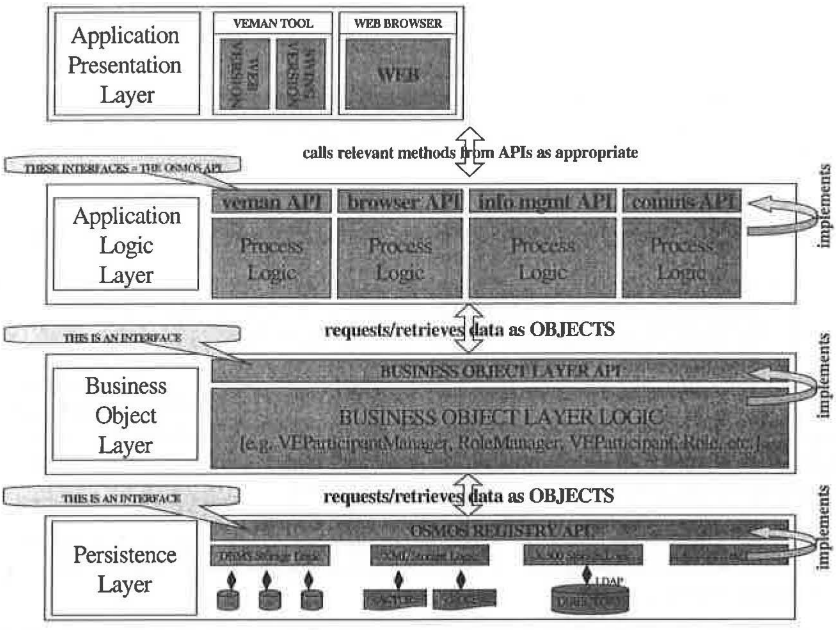

Figure 6: The Proposed OSMOS Architecture

The Business Object Layer contains a set of objects that are technical implementations of real-world objects/concepts, such as *Actors*, *Roles*, *DefaultAccessRights* and *InformationElements*. It is envisaged that these are direct implementations of those classes defined in the OSMOS Models as described previously. In addition, this layer will also contain classes of objects that help "manage" these real world objects/concepts, (e.g. retrieving them from persistent storage, creating new objects, making these objects available to the Application Logic Layer via a standard API, etc).

The Persistence Layer would provide generic services for the storage and retrieval of such objects from various forms of persistent storage (such as Object Databases, Relational Databases, X.500-based Directories or even simple Java Serialisation). It is envisaged that these services can reuse, and/or enhance, those already available in the Open Source community.

Both these layers would be generic to, and used by, all applications within the OSMOS infrastructure. The Application Layer, which uses the objects from the Business Object layer, provides services for manipulating these objects. This would be different for each application that is developed within OSMOS. For example, the "VEMAN" (OSMOS Virtual Enterprise Management Tool) would provide services for assigning Roles to Actors and vice versa. Each of these applications is accessed by its own user interface (in the Application Presentation Layer) which may, or may not, be web-based depending on the requirements of the End Users. In addition, this layer would also provide the OSMOS Generic Services (such as services for supporting Workflow, E-mail based Communication and Notification mechanisms) that may be used in multiple applications. Each of these Services and Applications would make their services available to the user interfaces and other applications at the Application Presentation Layer through a generic set of APIs ("the OSMOS APIs").

Finally, it must be noted by the reader that some applications (which are not pictured in the diagram) that are currently used by the project's End Users will also be integrated into the OSMOS Architecture. These will be integrated through the use of 'wrappers' around their existing applications so that these don't need to be re-written.

CONCLUSION

The paper presented the European OSMOS project, which involves leading research and academic institutions, along with key industrial players, in the building and construction domain. The OSMOS methodology was described along with the Use Cases, Sequence Diagrams, Object Models and System Architecture underlying the OSMOS infrastructure. It is worth mentioning that the services that OSMOS will provide are expected to enable software currently used within the Construction Industry to be integrated with traditional groupware-type 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 a few weeks as opposed to months, as is the case today as regards the deployment of Electronic Document Management (EDM) and Product Data Management (PDM) systems in construction companies. The project end-users are currently involved with the deployment and interpretation of the proposed system architecture within their organisation, to set up internet-based teamwork 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. Finally, the consortium would like to acknowledge the support of the European Commission under the IST program (IST-1999-10491).

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