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TOWARD THE DIGITAL CONSTRUCTION VIRTUAL ENTERPRISE

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ABSTRACT

The paper presents an overview of the methodology and findings of the ongoing OSMOS project.[1] OSMOS aims to highlight and go some way to meeting the needs of the industry by providing a set of tools, models, APIs and techniques to support the construction "Virtual Enterprise" (VE). Key to the OSMOS approach is that the tools will allow companies (especially SMEs) to partake in a project-based VE quickly and at a low entry-level. Through a combination of IDEF0 and UML modelling, within an iterative and incremental project methodology, the OSMOS consortium has elaborated a generic process model for the set-up and structuring of the construction Virtual Enterprise, which has formed the basis for the technical implementation of the tools and API. The tools, once designed, built, and made available for testing, have been evaluated within construction based case scenarios by end-users, and subsequently refined and re-tested. The resultant solution being offered through the OSMOS approach will involve some potential process changes within the companies wishing to take part in the VE, and the project aims to provide a proposed migration path to this end.

1.   INTRODUCTION

With the convergence and widespread acceptance and use of information and communication technologies (ICT), the notion of "Virtual Enterprise" (VE), amongst others, has engendered interest in many industry sectors. Numerous definitions of the term (including 'virtual organisation' and 'virtual corporation') exist in the literature, for example Goranson, 1999, Tapscott, 1996, Dutton, 1999. It is not intended to offer a new definition here, but it is important to note that generally the VE is defined by the organisations and groups involved, characterised by their geographical dispersion and supported through the use of ICT. The authors believe that the agreements made between the relevant actors are also a key feature. Such agreements will include both the extent to which information and knowledge are managed and shared, and the tools made available to do this.

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[1] OSMOS (http://cic.vtt.fi/projects/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 IT service providers: *DERBi, JM, Olof Granlund,* and European leading research centres and academic: *CSTB, VTT, and Information Systems Institute* of University of Salford.

This paper presents a high-level overview of the methodology and findings to date of the ongoing Open System for Inter-enterprise Information Management in Dynamic Virtual Environments (OSMOS) (IST-1999-10491) project. OSMOS aims to highlight and go some way to meeting the needs of the industry by providing a set of tools, models, APIs and techniques to both support and enable the construction VE. This is being achieved via the specification of Internet-based services providing interconnection through semantic cross-referencing of objects held in different applications, coupled with an efficient VE management set-up.

1.1.   Construction industry context

Rather than the VE being a new organisational form arising from the capabilities of advances in ICT and globalisation, it has been noted elsewhere (Rezgui *et al*, 2000) that the construction industry has for decades adopted the *modus operandi* of the VE. It is characterised by non-collocated teams of separate firms who come together for a specific project and may then never work together again. Furthermore there is generally no dominant actor to enforce ICT solutions, information exchange is not normally contractually controlled, and the industry is project oriented with all actors being involved in numerous VEs concurrently.

Organisations and individuals participating in construction teams bring their own unique skills, knowledge and resources, which include proprietary and commercial software applications. The ICT solutions employed on construction projects tend to be fixed rather than open, and frequently lack support. They are often prohibitively expensive particularly for small to medium sized enterprises (SME), and offer only limited growth paths in terms of hardware and software. Furthermore there is often a requirement to organise the enterprise around the adopted technological solution.

Due to these characteristics various problems have been identified including the following:

- ICT support to handle 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.

- ICT 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.

1.2.   OSMOS objectives

The overall aim of the OSMOS project is to enhance the capabilities of construction enterprises to act and collaborate effectively on projects by setting up and promoting value-added Internet-based flexible services that support teamwork in the dynamic networks of the (European) construction industry. These Internet-based services should allow collaboration between dissimilar construction applications and semantic cross-referencing between the information they manipulate, and the co-ordination of interactions between individuals and teams in a dynamic construction VE. The work should also specify and implement 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. Provision will be made of low entry-level tools (cheap and user-friendly) to allow small enterprises to act and participate in construction VEs, and to allow end-users to use their familiar proprietary and commercial applications on projects. Key to the OSMOS approach is that the tools will allow companies (especially SMEs) to partake quickly to a project-based VE. Two OSMOS Internet-based teamwork service providers will be set up. The definition of a migration path to using the OSMOS approach and analysis of its likely benefits will ensure take-up of these service providers as commercial offers after the completion of the project.

687

2.   REQUIREMENT CAPTURE FOR THE CONSTRUCTION VE

Requirement for the proposed system was provided by an analysis of the current business processes and information management practices (both intra-company and inter-company) within the end-user organisations in France, Finland and Sweden. An analysis was also made of their currently used software applications. By abstracting from these models a Generic VE Process Model (GVEPM) was designed to determine the high-level process activities.

2.1.   Business process and information practices analysis

The information input to the process models was provided by the end-user organisations, based on their current working methods in the construction industry, and detailed in IDEF0 format (NIST, 1993). It is worth mentioning that the consortium was aware of the limitations of IDEF0 alone for process description, and for this reason an OSMOS standardised format was created to provide capture of further information related to each process / functional activity. This format allowed the end-users to present their current processes as IDEF0 diagrams, and to include additional information as required. This information included a description of the activity being modelled and the operational context in which it is applied. Additionally, the actors involved in the activity, any existing pre-conditions and / or post-conditions, exceptions, and other remarks pertinent to the activity could also be provided. The resultant models (The OSMOS Consortium, 2001*a* appendices) provided a comprehensive view of the intra-company business activities and the methods of information handling between actors. This formed the first step towards the specification of the OSMOS generic solution.

2.2.   Analysis of interactions between teams on projects

This phase focused on the current management of teams and other actors in the context of a VE, which provided a comprehensive view of the inter-company interactions of the actors commonly involved in a construction project. The results indicated the many variables to be taken into account during the life of a VE. It became clear that a VE in the construction industry is contemporaneous with the lifecycle of any specific building project. Depending on the actors involved therefore, a single VE may for example exist for the complete lifecycle of a building, whilst others may exist only during a specific phase such as design, or facilities management (FM). Different phases would require different infrastructures, available services, information management practices, and so on. Other variables to be taken into account include: agreement of procedures and protocols, contractual agreement, setting up of a VE administrator account, training of personnel, management of change (including actors, classes, access rights, information, infrastructure and configuration data, rapid change in technology, the building itself, etc.) and data security and transfer.

The models (The OSMOS Consortium, 2001b) highlighted the interactions and processes that were common to all of the end-user companies, and also those that were specific to each. The combined results provided the basis for the GVEPM. Before presenting the GVEPM, however, it is important to note that the analyses also identified three distinct roles that would interact to both enable and make use of OSMOS in a typical VE setting. The three roles are:

- *OSMOS Service Provider (Role A):* The companies adopting this role are primarily concerned with hosting the OSMOS core infrastructure through provision of and access to both OSMOS core services and third party services (TPS). Role A, through the OSMOS core, has the capability to host multiple VE projects and to make available different services (both core and TPS) to different projects.

- *OSMOS Third Party Service Providers (Role B):* These companies plug-in their services and register associated methods through a Role A provider and make them available for use in a VE. Typically, these services would be geared to serving a particular purpose for the VE to

688

which they are being made available. Examples of these services include HVAC, facilities management, document management, CAD services, etc.

- *OSMOS Clients (Role C):* These companies use, and take part in VEs that are supported and enabled through the OSMOS platform. While one company would configure and administer the VE, others would make use of the core and TPS services made available to the project.

In brief, therefore, Role A provides the OSMOS platform and core services, Role B provides some specific TPS applications, and Role C makes use of the OSMOS core and TPS to enable inter-enterprise information exchange in the VE(s) in which it is participating. It must be noted that the three roles are not necessarily exclusive to a specific company. For example a company acting in Role A may also provide one or more TPS, therefore taking on both Role A and Role B.

2.4.   The OSMOS generic virtual enterprise process model (GVEPM)

At the highest level the model represents all the actions required to *Manage and Use the OSMOS* platform to run a complete VE Project from initial client requirements to the end of the contract. (See The OSMOS Consortium, 2001*b* for the complete IDEF0 model). The management and use of the OSMOS platform was found to decompose to two key activities. Firstly, *Provide and maintain VE Services* incorporates the processes required to provide and maintain all services currently available to companies that wish to run a VE. This activity is equivalent to the OSMOS Role A, and must provide and register the availability of TPSs, maintain them once provided and remove or replace them as changes in technology and / or requirements dictate. Secondly, *Provide and Maintain VE Project* is the totality of processes required to run any individual project. A project management committee would be formed and a contractual agreement made between the actors (including the OSMOS Role A company) involved in the prospective VE, and these then control the processes required to set up and configure the particular VE project environment and operate the project from inception to completion. The activities required to operate a VE project, once configured, are shown in Figure 1.
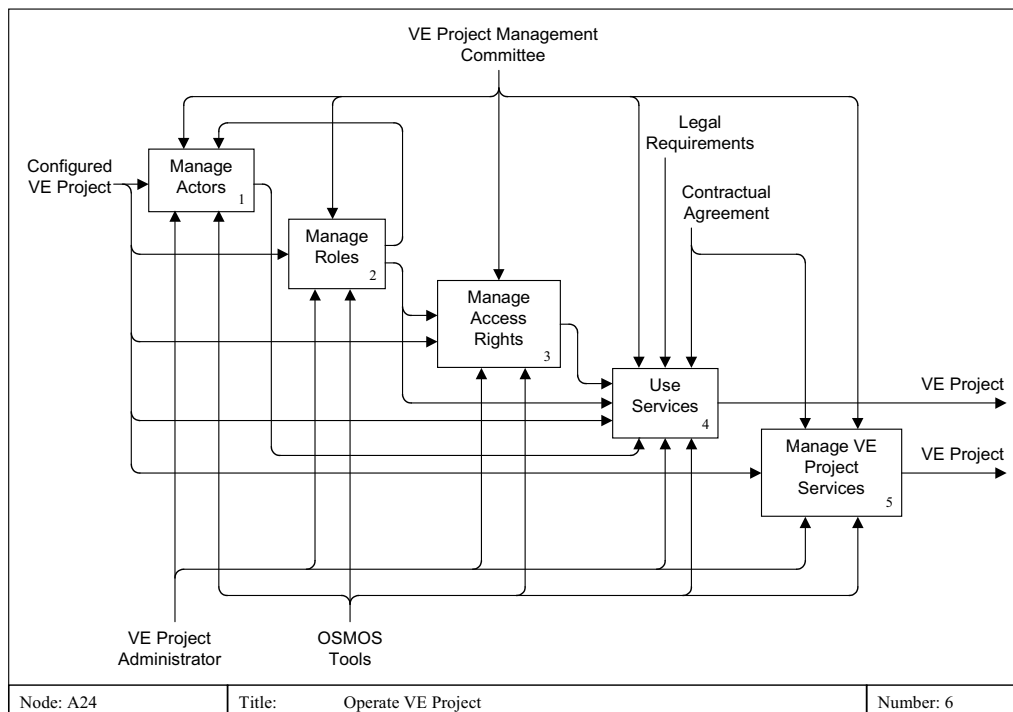

Figure 1: Operate a VE Project

The concept of actors and their roles and access rights was very carefully considered in order to keep the OSMOS solution as generic as possible. Any one project (and therefore VE) comprises a set of

689

actors at the organisation / company level, a unique set of individuals, required services, information objects, and varying degrees of access to services and information depending on legal, contractual and intellectual property rights (IPR) considerations.

One or more individuals within one or more companies / organisations will hold a specific project role. It is through the project role that access rights will be given to an individual within the project. A project role in one VE, however, may not necessarily have the same profile in another VE, even where the actors for the two VEs may be exactly the same (due to the fact that the agreements, protocols and procedures will differ). The result is that through the OSMOS approach access rights are assigned to specific defined roles, which themselves are assigned to actors at the company / organisation level within the VE. The company / organisation then delegates the available role to the individual(s) as required.

3.   SPECIFICATION OF THE OSMOS PLATFORM

The GVEPM determined the high-level process activities. At a lower level the Unified Modelling Language (UML) (Object Management Group, 1999) was employed to detail (via Use Cases) the ways in which the OSMOS system can be used and to derive the required functionality of the system. The ensuing Use Cases were the bridging link between the requirement capture and the system specification. Each node at the lowest levels of the GVEPM was further decomposed and described as a set of Use Cases describing how the OSMOS platform would be used at a business level. An example Use Case is provided here to illustrate the process (Figure 2) – the registration of a Role on a Project (from the IDEF0 node A242 *Manage Roles*, see Figure 1 above).
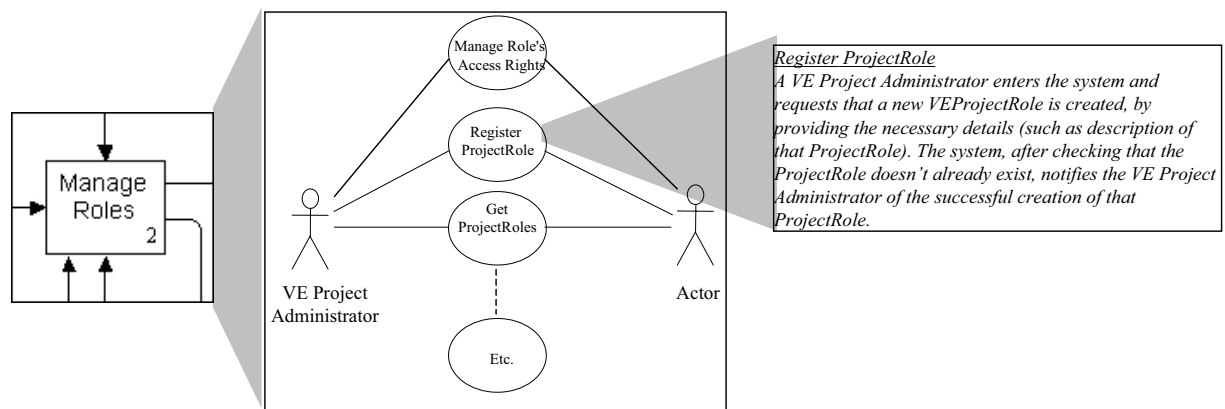

Figure 2: From process models to Use Case descriptions

The *Manage Roles* process was broken down into a number of individual Use Cases. Each Use Case was then described in a textual format that stated who performed it and what that actor expected the OSMOS System to do. The example given is for the *Register ProjectRole* Use Case. A complete formal description of each of the Use Cases and their corresponding textual descriptions are provided in Marache *et al.,* 2001.

From the Use Cases, the OSMOS Project used an Object-Oriented approach to system design, which itself is a subset of the Rational Unified Process (Rational Corporation, 2001). The textual descriptions of the Use Cases were examined through *Noun Phrase Analysis* to provide attributes, *Actors* (human users or external systems), and thereby a list of *classes of objects* that would be required by the OSMOS System. The resulting *classes* were then used in the conceptual modelling and design of the System. Each Use Case was also analysed to decide how the *classes* and *objects* would interact within the OSMOS System, to satisfy the expectations of the calling *Actor*. The results of such analysis were presented as UML Sequence Diagrams, which helped to discover the *methods* or *services* provided by such objects. Furthermore these diagrams aided definition of the OSMOS API in terms of the

690

architecture of the OSMOS System and further classes required for purely technical reasons (for example *Database* objects for persistent storage). The process was repeated in an incremental and iterative fashion, allowing benefits such as increased stability, validity and levels of synergy within the results.

A major output of the OSMOS Project is a robust set of models that show the underlying philosophies and business logic that would be enforced by the implemented solution within the context of a VE. The models, which have evolved from the analysis and design phases discussed above, have also been influenced by the careful analysis and simplification of relevant parts of the models produced in other projects such as COMMIT (Brown *et al.,* 1996) and CONDOR (Rezgui and Cooper, 1998).

The models that have been defined at the time of writing are a set of models concentrating on the *High Level Security Service* and *Semantic Information Management.* In addition, models are being developed that refer to *Communication Services* within the VE. The OSMOS High-Level Security Model evolved from an earlier OSMOS Distributed Object Management Model (Harvey *et al.,* 2001). It is concerned with the management of the Actors, Projects and the overall provision of the VE. It attempts to address some of the primary issues that are central to management of a VE such as: rights & responsibilities and contractual obligations. The OSMOS Information Management Model covers information versioning, ownership classification, and the semantic relationships between pieces of information.

In addition to the aforementioned models, the OSMOS API defines a set of API calls for both the High Level Security Service and the Information Management Service. This API (detailed in Marache *et al.*, 2001) is technologically neutral and can be invoked in a variety of ways.

3.   IMPLEMENTATION OF THE OSMOS PLATFORM

The OSMOS platform is designed to federate services, including distributed, heterogeneous programs developed by several companies, inside a common framework, thus allowing their use and collaboration. The OSMOS framework handles two categories of Services: Core Services and Third Party Services (TPS). The Core Services are the heart of the OSMOS framework. They are Role A components designed, developed and maintained by OSMOS framework providers. They provide common functionalities for every OSMOS-enabled VE information system, such as Actors management, Roles management, Projects management, and so on, by implementing the OSMOS APIs. TPS are Role B applications made available via the World Wide Web. They provide high-level tools (Facilities Management, Building-oriented EDM, etc.) to the Role C end-user to enable working in the VE, and they rely on the OSMOS Core Services to work within an OSMOS framework (using features such as Cross-Referencing, Access Rights Management, Actors Management, etc.) The framework is an entry point for accessing TPS, and the user, according to his or her role will use them transparently in the VE.

All the programs described above are Java Objects (http://java.sun.com), local to the Java Virtual Machine (JVM) where they are running, with Remote Method Invocation (RMI) technology allowing access to the OSMOS API. Java was the chosen technology due to its native Distribution features, but it is worth mentioning that the whole framework could have been implemented using other technologies such as CORBA or COM+.

The OSMOS framework had also to provide technology-neutral access to the Role A Server. As the framework is entirely Java based and accessible by only the OSMOS API Invoker, an interoperable layer (the 'X' layer) based on XML was built on top of this component. The key concept is both to describe and return method calls in XML. This approach is strongly inspired from the SOAP and XML-RPC specifications from the World Wide Web Consortium, and was implemented at a time when SOAP was not fully mature.

691

Several tools (as reference implementations) have been developed providing user access to the OSMOS platform. These tools include:

- Role A Server Tool – implemented using Java Swing classes, it provides functionality to a Role A Server Administrator to manage the server.

- VE Server Administration Tool (Figure 3) – presented using Java Server Pages, it offers a web-based environment facilitating the configuration and maintenance of the Role A server.

- VE project Administration Tool – basically a subset of the VE Server Administration Tool – allows configuration and management of any VE project. Once a project has been set up, control is passed over to a "VE Project Administrator" who then uses this tool.

- Web-based Information Browser – which acts as a low-level entry environment to the OSMOS workspace. This tool presents to VE participants, based on their roles and associated access rights, the different objects and associated service methods to which they have access.
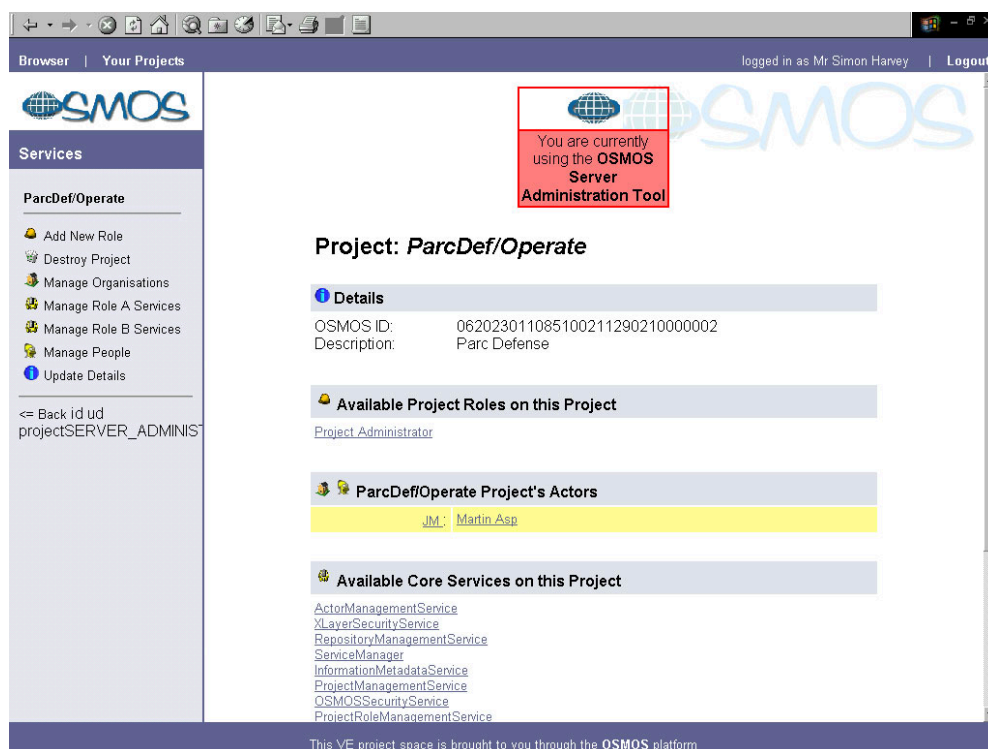

Figure 3: Reference interface of the OSMOS Server Administration tool

TPS registration via the Role A Server tool allows Role B services to be integrated at any time into the OSMOS framework, and its available methods and associated parameters identified. From this point the service from the perspective of the end-user (VE participant) is no different to a core service. The actual difference is that method invocation on the service takes place at the service provider (Role B) end rather than at the Role A. This transparency means that the user needs no specialist technical knowledge, a consideration at the heart of the OSMOS approach, as this is frequently the case within construction SME.

4.   TESTING AND VALIDATION OF THE OSMOS APPROACH

The principal means of testing and evaluating the OSMOS approach is being provided through field trials simulating work in a construction VE. Criteria have been determined for technical, social and economical evaluation of the OSMOS system together with legal, contractual and organisational

692

aspects. Throughout the project the consortium has recognised that the integration of human, organisational and technical elements is a prerequisite for a successful specification of the strategy required to identify and implement the potential changes resulting from the proposed OSMOS approach. The research has therefore included analysis of factors often neglected in similar industry / business and ICT research efforts. An IT and Construction questionnaire was completed by employees working at the operational / tactical level in the end-user organisations, and provided initial company profiles. Further to the questionnaires, semi-structured interviews were also carried out with more senior people at the tactical / strategic level. Results from this research provided initial validation of the OSMOS approach and the requirements of the resultant system being developed, plus valuable information that, coupled with the results from the final field trials, will ultimately enable the formulation of business recommendations.

Various commercial web-based electronic document management systems are already available, offering document and workflow management services across the Internet, some of which are tailored specifically to the construction industry. Such solutions include offerings from Bricsnet (http://www.bricsnet.com), Buzzsaw (http://www.buzzsaw.com), BuildOnline (http://www.build-online.com) and Citadon (http://www.citadon.com). The services offered by these companies are, not unsurprisingly for commercial ventures, basically closed; for example Buzzsaw emerged as a spin-off from the design-software company Autodesk, and thus offers Autodesk software solutions. The OSMOS approach differs in its objectives in this respect, aiming to integrate services from many organisations, even making available alternative versions of the same service, in an open way (and not merely as a Web link to a vendor). This 'plug and play' provision of third party services thus emerges as the unique selling point of the OSMOS approach, key to which is the unique OSMOS API.

Overall the field trials aim to address three high-level concerns: to ensure that the proposed system works (i.e. to evaluate its usability); to ascertain that it meets and achieves its intended business goals; and to ensure its acceptance by the intended users. The field trials carried out to date have been based on separate work scenarios within two of the end-user companies in France and Finland, and have allowed evaluation of the GVEPM, the OSMOS VE Server Administration tool and the OSMOS VE Project Administration tool. In the French field trial the OSMOS tools were manipulated to simulate the set-up and management of a construction VE. The individuals taking part, including IT and construction professionals, represented the roles of VE Server administrator, TPS provider, VE Project administrator, and VE Project participants. The Finnish field trial testing scenario involved using the OMSOS VE administration tools to set up a new VE and the use of a proprietary web enabled FM software application. Representations of a Building Owner, Maintenance Company and a Facility Consultant were created as organisation actors, to which employees were registered and given project roles with access to specific services.

Analysis from the field trials showed generally satisfactory results regarding usability of the tools, though it should be noted that these were reference implementations only and it is expected that VE service providers will ultimately design their own interfaces for exploitation purposes. The results validated the GVEPM in terms of the processes involved in administering the VE at both the server and project levels. The activities within the GVEPM that relate to providing, maintaining and using TPS and other services are logically straightforward and do not impinge greatly on the model overall. It is expected that once field trials have been carried out to test the complete OSMOS approach the GVEPM (and therefore the underlying functionality of the OSMOS tools) will prove to be accepted throughout. The trials also validated the OSMOS Roles (A, B, and C). The roles were accepted as a strong and logical underlying concept within the OSMOS consortium, and it is an excellent result that the users who took part in the field trials – who were not previously associated with the project – found agreement in these concepts.

In terms of the OSMOS API, again the evaluation will only become truly apparent from the final field trials, when the OSMOS platform is tested with a complete set of services available. During the French trials, however, a proprietary EDMS was registered / deregistered from the framework very easily, which also augurs well for the rapid set-up of a VE in which Role C SMEs can take part.

693

The field trials so far carried out in the project have served as a good interim evaluation for specifics of the OSMOS approach. However, in order to test the true added value of the OSMOS approach, and also to enable objective business process recommendations and a strategy for implementing the OSMOS method, final full-scale field trials are required. The critical success factor required for these trials is full integration of TPS, accessible over the Internet to OSMOS Role C actors. Such field trials are currently being planned, involving all three OSMOS end-user organisations.

The approach taken in OSMOS will inevitably lead to some business process re-engineering, and as the processes around which the system is based are generic, there may be some need for training within companies wishing to enable their construction VE through OSMOS. In defining and recommending the GVEPM, it is not the intention of the OSMOS consortium to prescribe a rigid methodology to be imposed on the companies that wish to join an OSMOS powered VE or indeed the industry in general. Rather the intention is to show that the processes have been tested and accepted as beneficial, and that adoption of those processes will facilitate the migration path. The specific inclusion in the GVEPM of processes for making the contractual agreement for the VE project and agreeing the management protocols and procedures, ensure that the actors involved in any particular VE can be sure that their agreed methods of working control the necessary activities throughout, and are therefore adhered to integrally. It was possible to make some preliminary business recommendations specific to the companies involved in the project from analysis of the interim field trials results, combined with the research into human and organisational issues. It is the intention of the OSMOS consortium to be able to make business recommendations relevant to the construction industry as a whole in terms of adopting the OSMOS approach, following the final field trial.

5.   CONCLUSION

The OSMOS project aims to provide a generic open platform to enable construction enterprises, including SMEs throughout the European construction industry to enhance their current capabilities. This will be 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 VE and projects 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 recognises the importance of human and organisational issues to ensure that the OSMOS consortium can define the likely benefits of adopting the OSMOS approach and recommend a migration path to that end.

Finally, the OSMOS project is taking part in two strategic initiatives funded by the EC under the IST programme: the VOSTER (Virtual Organisation Cluster – IST-2001-32031) project, involving 23 organisations across Europe, and the ICCI (Innovation co-ordination, transfer and deployment through networked Co-operation in the Construction Industry – IST-2001-33022) project. The latter is construction industry specific, whilst the former is open across sectors. These cluster initiatives aim at achieving cross-fertilisation of projects results in the area of ICT support for the VE, with the strategic goal of impacting on standardisation and enhancing the competitiveness of European industry in the digital economy.

6.   ACKNOWLEDGEMENTS

694

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