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Cloud-Marketplaces: Distributed e-procurement for the AEC sector

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ABSTRACT

The development of web-based collaborative platforms, BIM, and transactional e-marketplaces has been changing the way companies in the AEC sector work. However, due to interoperability issues, the main problems of distributed data and information management across AEC companies and projects are yet to be overcome. This paper presents the Cloud-Marketplace concept, which expands on earlier developments combining BIM, SOA, Cloud Computing, and e-marketplaces in order to create interoperable communities of e-platforms. The Vortaway case study is described to demonstrate the validation of the concept in simple AEC e-procurement processes.

1. Introduction

Despite its presence in many economic sectors, the widespread use of electronic commerce still falls short of reaching the tipping point in the Architecture, Engineering, and Construction (AEC) sector. The emergence of the Building Information Modeling (BIM) approach, already implemented in many construction projects, has mainly focused on the technical aspects of project conception and execution, addressing the increase of effectiveness in visualization, coordination, and planning processes. Web-based collaborative platforms are also emerging as effective support to collaboration, information management, and sharing, stimulating easy and stable communication, and the convergence of this type of mechanism with BIM-based tools and traditional transactional based e-marketplaces has also become a reality. However, these developments have not been able to overcome much of the interoperability of the AEC sector that would make possible truly distributed data management within and across companies and projects in the sector.

This paper proposes a conceptual approach for overcoming some of the shortcomings of earlier researchers' and practitioners' approaches. The paper is organized as follows. Section 2 reviews the current state of play of e-marketplaces and their main challenges in the AEC sector along with the emerging trends of BIM, Cloud Computing, and SOA. Section 3 lays out the Cloud-Marketplace concept for the development of new transactional and collaborative e-marketplaces, grounded on previously developed work in the SOA4BIM framework along with new concepts regarding distributed information and data management based on MDA, SOA, and Cloud Computing. Section four presents the Vortalway case study, describing part of the validation and implementation of the conceptual model. Finally, Section 5 concludes, with some words on the relevance and applicability of the Cloud-Marketplace approach and the challenges to its development.

2. Promises from BIM, SOA, and cloud computing

2.1. Current challenges for e-marketplaces in the AEC

Electronic procurement (e-procurement) emerged from the early adoption of the Internet by business, and the AEC sector early on followed the emerging trend [1]. In the early days e-procurement by AEC companies was linked to the surge of inter-organizational project management systems, communities, electronic platforms, meeting places, virtual locations, and infrastructures, often designated as electronic marketplaces (e-marketplaces) [2–4]. An e-marketplace is a virtual space in an electronic network, an inter-organizational information system that allows the participating buyers and sellers to exchange information about prices, product offerings, and an Internet-based electronic commerce platform that matches multiple buyers and suppliers in transactions along with traditional project-based collaborative functions.

Despite the widespread use of e-maketplaces with transactional and collaborative functions, there is today a plethora of electronic formats, product descriptions, and classification schemes, seeking to provide guidelines for the exchange of data between AEC agents, and regarding e-procurement especially, the challenge of having electronic catalogs (e-Catalogs) among buyers and suppliers [5]. Apart from the need for standardizing processes and messages for conducting business electronically, the adoption of additional standards is necessary for unifying the manner in which products

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and services are described in projects in a digital format. Besides the e-Catalogs issues, e-procurement presents several additional technical challenges that create interoperability concerns regarding electronic marketplaces at the European and global scales, and that are being addressed by several R&D and industry initiatives. For example, European public tendering procedures require that companies submit certificates and attestations to prove that they comply with selection and exclusion criteria. Electronic business certificates that are interoperable are thus one of the major challenges [6]. Electronic signatures interoperability is also an important issue, despite the availability of technical standards, such as X.509v3 for electronic certificates. However, even though electronic signatures are relatively widespread today, in practice certification authorities do not recognize each other in every case, thus creating identification hurdles. Other less challenging issues are e-ordering and e-invoicing, as the ongoing standardization work in CEN/ISSS WS/BII [7] is becoming mature, and these business documents are now standardized and XML-based (at least for system to system communication).

As a consequence of these hurdles, there is today clearly an interoperability problem between AEC agents within e-marketplaces. However, where the interoperability is more acute is across e-marketplaces, since most e-platform vendors are not prepared to allow interoperability between AEC agents that are located in disparate e-marketplaces.

2.2. The converge of BIM, SOA and cloud computing for e-marketplaces

Parallel to the deployment of traditional e-marketplaces for transactional and collaborative purposes, the use of the Building Information Modeling (BIM) paradigm has emerged, which improves project quality and empowers collaborative work, while giving the supply chain a more integrated perspective [8,9]. According to Ref. [8], using BIM technology makes it possible to construct an accurate virtual 3D and parametric model of a building containing precise geometry and relevant data needed to support the construction, fabrication, and procurement activities necessary for the building process. It promotes collaboration, integration, and process automation; it makes virtual reality simulations possible and fosters visualization and project understanding [10]. Web-based collaborative platforms are also emerging as effective support to collaboration, information management, and sharing, stimulating easy and stable communication [11,12], and an interesting synergy exists between web-based collaborative platforms and BIM, exploited progressively by innovative electronic platforms that promote a collaborative and integrated environment.

Grounded on the latest architectures, such as Model Driven Architecture (MDA), Service-Oriented Architecture (SOA), and Cloud Computing, and the developments in the construction sector with BIM, the SOA4BIM Framework has been developed striving for web-based collaboration and transactions based on BIM models [5,13]. The approach relies on the development of a Computational-Independent Model (CIM), that will model the design, construction, and maintenance building processes and products in a way that is not constrained by the requirements of the ICT platforms, i.e., only from a technical and business perspective. CIM can be grounded on some of the work previously developed, such as the Process Protocol Model [14], or on the work being developed more recently by the building SMART Initiative and its Information Delivery Manual (IDM), which is developing reference Process Maps for the whole construction process life-cycle [15]. Additionally, high-level e-procurement processes based on current developments of CEN/ISSS BI are adapted and modeled at the CIM level.

Deriving from CIM, the SOA4BIM framework considers the design of the Platform-Independent Model, which will be a technology-neutral modeling of the various types of information in a construction project: 3D vectors material composition, project management (costs, time, etc.), contractual arrangements, sustainability, etc. In reality, the PIM layer is essentially a standard approach to BIM, where much of the work carried out by *de facto* and *de jure* standardization bodies may be considered, and standards like the IFCs, AP 225, and AP 228 should be used [5]. For each project a PIM-BIM model is created in which many of the data structures can be reused by the agents involved, since it utilizes neutral formats. The integration of SOA with MDA will enable an engine for transformations and services that will automatically generate Platform-Specific Models (PSM) such as Web-services, to each of the agents (client, architect, specialist designer, etc.). Hence, each time a service is evoked by any agent, there will be an appropriate automated transformation of the PIM to the specific PSM, through mapping. Conversely, whenever a construction agent requires the PIM-BIM model to be enriched with new information generated by their applications (e.g., Specifications or Bill of Quantities), new services would be made available, transforming the new PSM requirements into the enriched PIM-BIM model. Nevertheless, there must be a process of conformance testing in order to check whether the enriched data conform to the initial PIM-BIM model, or require an adaptation to the initial model.

The SOA4BIM Framework envisages that the model-morphisms between the different framework layers will occur during the whole construction project life-cycle (architectural processes, engineering processes, construction processes, procurement processes, etc.), where an initial PIM-BIM model will be dynamically enriched by the contributions of the various agents as needed. The SOA4BIM Framework sustains the importance of developing these model transformations in a cloud computing approach. This means that whenever a construction agent has (functional) services implying the exchange of data, information, or tender documents with other agents, they will trigger Web-services (or another SOA-based mechanism) over the cloud, and all model transformations and conformance testing will occur within the cloud, regardless of the physical location of the applications, databases, operating systems, or hardware. During these processes, which are naturally dynamic, Service Level Agreements (SLAs) can be established between the agents in order to have a baseline for conformance testing of the services that will be established. At the end of the process, each actor will have the required information to work with, without having to know which conversion processes occurred. At the same time, the enrichment of the PIM-BIM model will occur dynamically, without any major (human) intervention by participants.

Whereas the SOA4BIM framework has proved to be successful for BIM-based collaborative and transactional interoperability of AEC projects life-cycle, within e-marketplaces (see, e.g., [5]), pilot research has uncovered the challenge for sustaining interoperability across e-marketplaces. In other words, while it was possible to argue that the application of the SOA4BIM Framework in the context of e-procurement is foreseen to overcome many technological barriers by re-using much of the standardization and research work done in the BIM and AEC sector, namely the IFC and STEP standards, and at the same time use current technology, like Web-services, for implementation, when AEC agents (architects, owners, contractors, builders, merchants, etc.) wish to interact with agents in other e-marketplace communities, the interoperability problem arises. To overcome this challenge, the Cloud-Marketplace concept has been developed. This paper is grounded on earlier research in which the concepts of SOA4BIM and Interoperability within bounded project-based organizations have been developed [13], along with research on the application of SOA4BIM for e-procurement purposes [5], and further expands it to include the concept of communities of electronic marketplaces and the