Collaborative Working Environments in the Construction Sector

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Abstract: This paper provides the design of an e-Business based solution for collaborative working environments tailored to the needs of the construction sector. This solution will improve construction companies' coordination by automatically logging any event that comes up at the construction site and reporting it to the affected partners so that they are able to react as soon as possible. A novel technological approach to deal with onsite collaboration in the construction sector is explained. The new approach relies on an e-Business platform and a Business Process Management (BPM) strategy instead of the more traditional solutions based on centralised applications. This approach, in contrast with traditional centralized strategies, offers important benefits for the SMEs participating in a construction project. The e-Business interfaces are independent of the PMC's management system allowing the SME to use always the same interface to receive and notify events. In addition, SMEs only deal with the information they need without being aware of the complexity of the whole project. However, despite these benefits, the new approach also imposes some new risks and challenges to the SMEs. The proposed approach is rather ambitious with regard to the current technology uptake in the construction sector and the deployment of this solution would imply some big cultural and organisational changes for the SMEs.

Keywords: Collaborative environments, e-Business, Construction SMEs, Semantics

1. Introduction

Unlike other industries, there are some peculiarities of the construction process, which influence the characteristics of built products, ways of production and the industry itself. Three of the main features of the construction sector are site production (i.e. production is always locally bound and dependent on factors such as soil and weather conditions), one-of-a kind production (i.e. most built objects are unique products due to design or context differences) and temporary organisation for purpose of separate projects (i.e. different firms and people team up for each project, not supporting knowledge transfer or systematic and long-term approaches to production and improvement) [1]. In short, this means that every construction project is different in design, building site conditions and people involved. Furthermore, a great number of different companies and people have to work together and be coordinated, at the same time and in the same place.

Ideally, the initial project planning takes into account the coordination needs of all the participants. However, the real situation is that many different unplanned events come up onsite affecting the initial planning and design. For this reason, the coordination onsite of all the actors involved in the project is one of the main issues in the construction sector.

A recent survey conducted over a set of Construction SMEs from five European Countries confirms this fact. Practically all the companies interviewed agreed that one of the main problems at the construction site is the coordination of all the subcontractors and suppliers [2]. Besides, companies are not always informed on time about incidents and document changes that affect their work.

ASCOBI, the Association of Construction Companies of Bizkaia (Spain), declared that "when a construction project finishes successfully, it is because the site coordination has been correctly managed".

2. Objectives

This paper provides the design of an e-Business based solution for collaborative working environments tailored to the needs of the construction sector. This solution will improve construction companies' coordination by logging any event that comes up at the construction site and automatically reporting it to the affected partners so that they are able to react as soon as possible.

A novel technological approach to deal with onsite collaboration in the construction sector is explained. The new approach relies on an e-Business platform and a Business Process Management (BPM) strategy instead of the more traditional solutions based on centralised applications [3 ECCPM][4 e-Challenges 2007].

Firstly, a conceptualization of the information and knowledge needed to deal with collaboration issues is presented.

Secondly, instead of designing a common repository for this knowledge accessible to every actor involved in the project, a Business Process strategy is used to define the way in which the information must be exchanged among the different actors involved in the building process.

This collaborative solution is the result of part of the work developed in the e-NVISION project, "A New Vision for the participation of European SMEs in the future e-Business scenario", a STREP project supported by the European Commission under the 6th Framework Programme in the action line "Strengthening the Integration of the ICT research effort in an Enlarged Europe".

3. Methodology

In a construction project, a great number of different companies and people have to work together and be coordinated: main constructor, subcontractors, designers, investors, material providers, suppliers of machinery, etc. All these actors need to share and reuse knowledge in computational form not only when making business-to-business transactions but also in their internal daily processes.

A recent study of IT usage and needs in the Danish construction sector [5 Danish] suggests that construction companies can be categorised into two main groups according to their business processes: "project-based companies" and "production/service companies". Production/service companies are suppliers to PMC companies, providing products (materials, equipment) or construction services (plumbing, electrical installation) on site.

Traditionally, Project Management Companies (PMC) use centralized construction management applications. This kind of applications cover all the construction phases and provide specific interfaces with which the companies involved in the project have to interact. There exist in the market specific tools for construction project management and collaboration like Primavera [6] or Aconex [7] among others. However, only big construction companies use such tools due to big initial investment requirements and the complexity of solutions. Most construction SMEs uses ad-hoc developments or general-purpose tools (like Lotus Notes of ERP products) with limited collaboration capabilities.

Furthermore, these applications are too complex and have several drawbacks for supplier SMEs (subcontractors, product, material and equipment suppliers). As traditional applications are designed to satisfy the PMC's requirements, they force to define the master schedule for the whole building project, whereas supplier SMEs are only interested in one or a few construction stages in which they are involved. Besides, the PMC's main concern is to monitor the schedule of one project, while supplier SMEs that usually provide materials or services to several projects are more interested in optimizing different scheduling constraints.

An e-Business approach benefits SMEs in two ways. Firstly, the e-Business interfaces are independent of the PMC's management system allowing the supplier SME to work with its own application and using the same interface in all construction projects. Secondly, the SME only deals with the information it needs avoiding being aware of the complexity of the whole project.

4. Scenario Context and Description

When a new construction project starts, the PMC prepares the initial project planning taking into account the coordination needs of all the participants, including the determination of key positions, for which interrelations between the planned works, supplies of materials and equipment, and dates of their earliest and latest completion must be set out. The Project Management Company (PMC) has to supervise construction in such a way, so as to effectively coordinate the activities of all participants as refers to construction and assembly works, services and deliveries of equipment and materials. The main objective of the coordination is the efficient and timely fulfilment of the tasks determined in the Master Schedule. The real situation is that many different unplanned events come up onsite affecting the initial planning and design. These events include changes in the initial design and delays in tasks due to breakdown of machinery or other causes.

Nowadays, when an event occurs at the construction site (e.g. a delay or a design change), it is very difficult to inform the interested parties (suppliers and sub-contractors) mainly because there is insufficient information sharing among the parties. Event notification is usually human based, via weekly meetings or even worse, by informal conversations on-site. These methods are very prone to errors and they do not take into account the product supplier companies, which are not involved in the work onsite.

Hence, many times the affected parties receive the incident notification too late to react accordingly and report the incident to their suppliers. This situation is even more problematic in the case of an SME because they lack the flexibility and recovery capability of big companies [8][9].

The future coordination onsite (e-Site) scenario's main objective is to coordinate operations on the site in real time taking into account the unexpected events that occur at the building site: breakdown of machinery, unacceptable weather conditions, absence of manpower, change in the documentation, etc.

The main functionalities of this scenario are:
- Provide event logging management facilities.
- Update schedules and site documentation according to the incidents and their consequences (the so-called reactive scheduling in [10]).
- Communicate events to the interested parties automatically by electronic means.
- Gather the response proposal to these incidents by the affected partners.

Based on collaborative modelling research works in the domain of architectural processes, the knowledge needed to deal with collaboration issues can be classified under the following concepts: Event, Task, Actor, Resource (material and device) and Document.

Once a new event occurs during construction site works, the proposed solution helps the PMC to answer the question: Which task(s), actor(s), document(s) or resource(s) is/are possibly affected by this event?

Next, the PMC has to notify the affected actors about the event and its implications. Finally, each company has to analyse how the event affects its own work. As a result of this analysis it may be necessary to start a negotiation process.

All events can be grouped by design document changes or schedule incidents. Documentation changes cover the events related to the document management system, that is, creation or modification of any site document (reports, logbook, meeting minutes, design documents, etc.). Schedule incidents cover all events related to scheduling and monitoring of construction works, including deliveries of machinery and materials. They also are related with the reorganization of works when a deviation is detected. Figure 1 shows a simplified example of the e-Site scenario functionality and context.
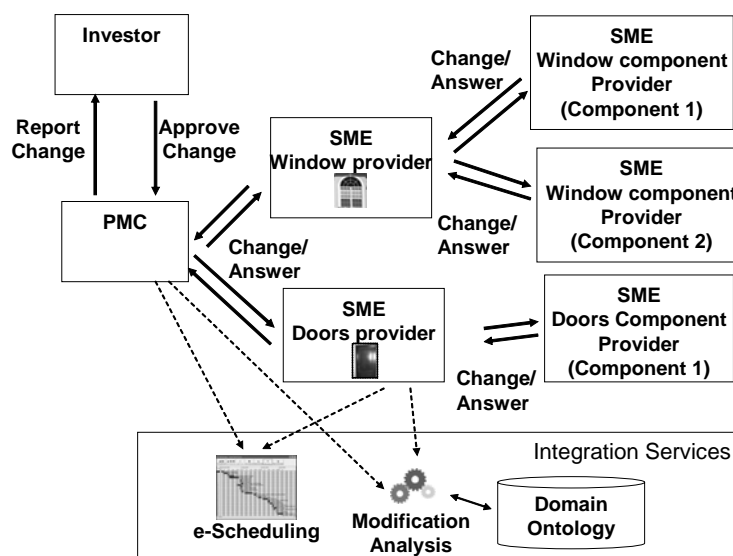

Figure 1: e-Site Scenario Example

The Project Management Company (PMC) is in charge of reporting and logging events. Once an event is signalled the e-Business collaboration solution helps the PMC to analyze its effects and decide which partners should be notified, like Windows and Doors suppliers in the example. Then, it notifies automatically the interested parties about the event and waits for the answer.

5. Technical Description

The e-Business based solution for the e-Site scenario is based on three technological pillars: Semantic technology, Business Process Management & Service Oriented Architecture. [11]

5.1 Semantic Technology

Since the proposed collaboration solution is based in the exchange of knowledge among disparate systems, semantic technology plays an important role in order to assure the semantic interoperability. To this end, an e-Business construction ontology [12][13][14] has been defined. The ontology provides the basic concepts in the construction and e-Business domains and the relations among them. The e-Business ontology for European Construction SMEs Collaboration (e-NVISION ontology) has been implemented using OWL (Web Ontology Language). The main concepts and relations modelled in this ontology have been grouped by several categories: Actor Domain, Business Domain, Item, Item Classification and User Criteria.

Besides, a domain has been defined to include the specific concepts needed for specific scenarios. Regarding the e-Site (Construction Coordination Onsite) scenario, the e-NVISION ontology contains a model of different events that can occur on site and the possibility of storing the links between these events and instances of documents, production activities/tasks, resources and actor concepts.

5.2 Business Processes and SOA Strategy

The proposed solution includes an event logging facility where the Project Manager can report a new event. Figure 2 shows the Event logging tool. This tool provides the starting point to the notification process.
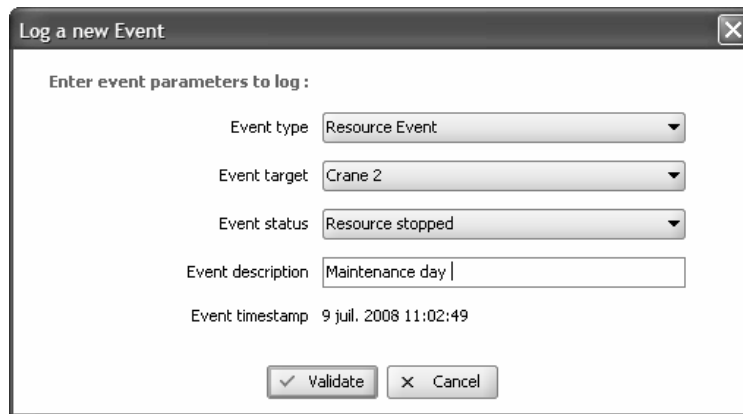

Figure 2: Event Logging Tool

Once a new event has been reported onsite a new Business Process is launched. The business process is implemented as a BPEL process deployed in a BPEL engine [15]. The next figure shows the business process deployed in the PMC.
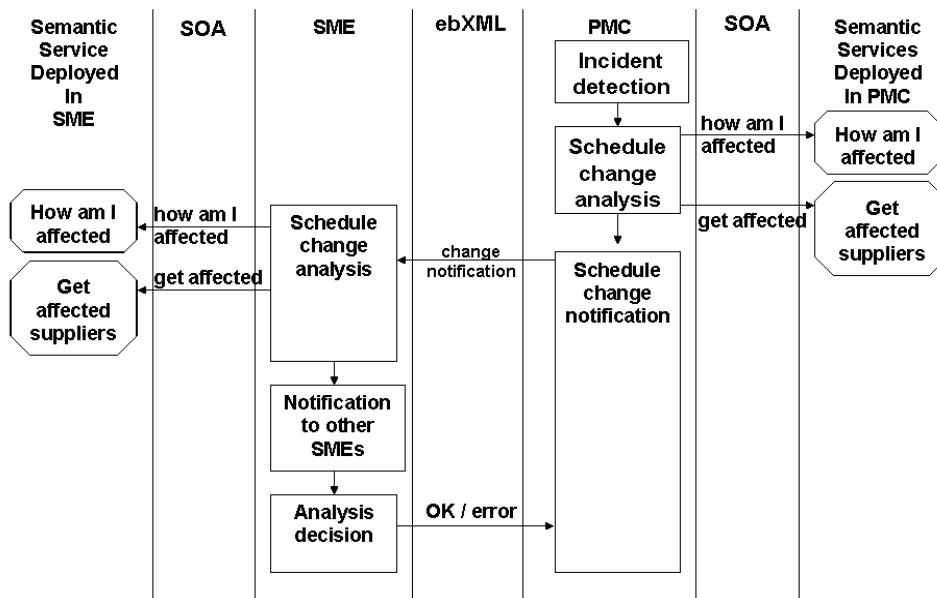

Figure 3: BPM Processes to Deal with a Delay Event

The process uses a semantic service in order to analyse the effects of the event. To do so, the process calls a semantic service (Document Content Management service) using a SOA strategy. The service uses semantic reasoning to provide the list of affected suppliers

by the event. The semantic reasoning is used inside the service to provide the following information:

- Relation between documents and tasks: What documentation is needed to perform a certain task or is related to the task?
- Relation between companies and tasks: What companies participate in a certain task?
- Relation between resources and tasks: What resources (device or material) are needed to perform a certain task?

Figure 4 shows the result of using the Document Content Management service applied to an event. Finally the BPEL process notifies the affected suppliers about the event and gather their answer, that can be simply an acknowledge or an error if the supplier is not able to deal with the event. The notification methods depend on the capabilities of the supplier being notified, going from an ebXML message [16], in the case of technologically advanced partners, to simple email notification or even SMS messages.
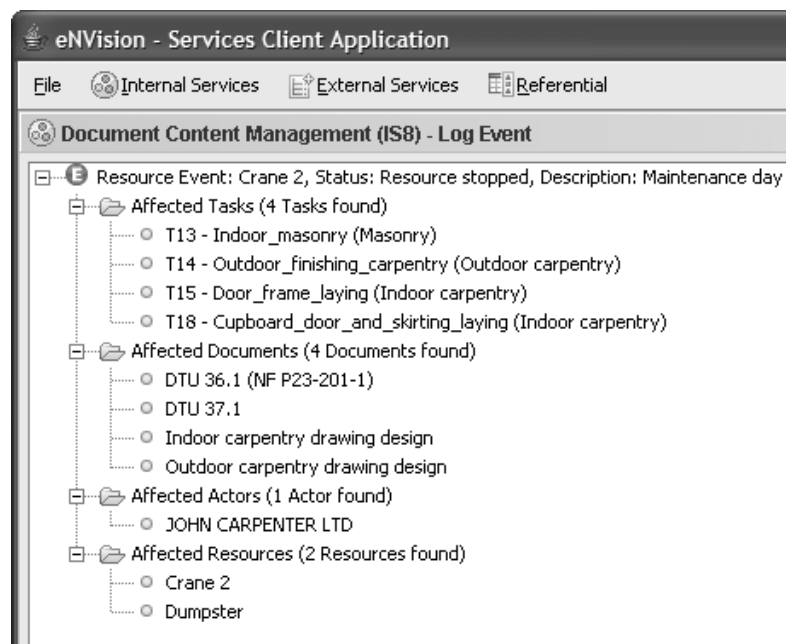

Figure 4: Analysis of Event Consequences

5.3 Developments and Results

The collaborative solution presented in this article is composed of three modules:

- Event logging tool: Provides the PMC with the event reporting and logging functionality and launches the BPEL process to deal with the event.
- Deployed BPEL process.
- Document Management Service.

Two of these modules have already been implemented: the Event logging tool and the Document Management Service. Regarding the BPEL process module, the process has been defined in BPMN and BPEL process are being implemented, based on the BPMN representation. An open-source ESB with BPEL engine (OpenESB) has been selected as the platform to deploy the BPEL processes.

6. Business Benefits

On the construction site the use of an empirical method matches with a work method based on the field know-how experience rather than a formalized process. Presently this approach

seems to meet real time feedback requirements on unforeseeable events as a project adapts oneself to the way of things.

In these occasions, the information is rarely real-time recorded: sometimes it is weekly "registered" in the site meeting report although sometimes it can be lost. And the information registered in the site meeting report is not always used to update design and preconstruction documents even in the counting task during the handover phase.

During the erection phase, the construction site becomes the nerve centre of the project and gathers a huge quantity of useful information available for the actors involved in the project, either mobile or not, either main contractor or subcontractor, and at the same time the information capitalized in this phase is all-important for the maintenance phase of the building until its demolition.

Taking into account construction site events can have efficient impact not only the execution, but also on the handover, maintenance, preliminary and design stages.
Such a practice is going to provide information which is usually lost on the construction site. The use of semantics event analysis can affect various resources of the project (actors, document, schedule, devices, material…), and presumably the result of the project, its realization cost and its over-all quality.

A survey has been conducted to validate whether the envisioned scenario was in the line of construction SMEs expectations and desired way of work and whether the coordination on the site was really a problem for construction companies. [2]

As a conclusion from the answers obtained, we can say that for 97% of the companies interviewed, the coordination of all the subcontractors and suppliers is one of the main problems at the construction site. Besides, more then 90% of the respondents agree or strongly agree on these three facts: document changes are not always reported to the affected partners on time; design documentation is not always updated; companies are not always informed on time about incidents that affect their work.

Moreover, the 80% of the companies interviewed consider that the e-Site envisioned scenario meets their expectations and desired way of work and that the proposed scenario will improve the construction work coordination.

7. Conclusions and Future Work

In this paper a novel approach to the design of a collaborative working environment in the Construction Sector is presented. This new approach combines an e-Business strategy, where the different events in the construction site are propagated among the affected partners, with a Business Process Management strategy, based on defining and deploying internal business processes to deal with the events.

This approach, in contrast with traditional centralized strategies, offers important benefits for the SMEs participating in a construction project. The e-Business interfaces are independent of the PMC's management system allowing the SME to use always the same interface to receive and notify events. In addition, SMEs only deal with the information they need without being aware of the complexity of the whole project.

The proposed solution has been validated by construction SMEs in five European countries [2] and the e-NVISION project has been included among the list of some major recent projects related to the ECTP SRA Implementation Action Plan [17]. The ECTP considers that e-NVISION has synergies especially with Items H6 (Collaboration support) and H8 (ICT enabled business models). Furthermore, it is the intention of the project consortium to follow the research line in the framework of the ECTP SRA in order to improve the defined e-Business scenarios and to develop new ones.

Finally, in order to validate the whole system in real working conditions it will be installed in at least two construction companies in two different countries.

However, despite its benefits, the new approach also imposes some new risks and challenges for SMEs. The proposed approach is rather ambitious with regard to technology uptake in the construction sector. The e-Business and BPM open source tools available in the market still lack the maturity level required for use in production environments while available commercial tools are too expensive and complex. Finally, the deployment of this solution implies significant cultural and organisational changes for the SMEs.

Acknowledgements

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