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A SERVICE-BASED INNOVATION PROCESS FOR IMPROVING COOPERATIVE PRACTICES IN AEC

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SUMMARY: *The design of software services to support activities in Architecture, Engineering and Construction (AEC) has been largely addressed in the "IT for Construction" research community. Nowadays prospective research efforts focus on Building Information Modelling approach and its capability to significantly improve the working practices in the future. Starting from "day-to-day" practitioners' requirements the research presented in this paper targets the issue of cooperation support in AEC projects. The methodology aims to closely involve researchers and practitioners from Luxembourg in the design of business services fitting their precise requirements. A generic "Sustainable Service Innovation Process" (S2IP) is applied to the issue of documents sharing in construction projects. The processes related to "service value" identification and to "service design" are described through 1) identifying best working practices with practitioners, 2) monitoring the end-users appropriation factors and 3) applying a model-driven engineering for developing business services aligned to AEC specific context. The paper presents a set of cooperative working practices related to document management, which have been mutually agreed between practitioners. The related business services are implemented in a software prototype, which is under experiment at present. The results are finally discussed in a perspective of business services appropriation by their future end-users.*

KEYWORDS: *Sustainable Service Innovation Process (S2IP), Business Service, Service Design, Document Management, Cooperative practices.*

REFERENCE: *Kubicki S, Guerriero A, Johannsen L (2009) A service-based innovation process for improving cooperative practices in AEC, Special Issue Building Information Modeling Applications, Challenges and Future Directions, Journal of Information Technology in Construction (ITcon), Vol. 14, pg. 654-673, http://www.itcon.org/2009/43*

1. INTRODUCTION

Cooperation between actors involved in Architecture, Engineering and Construction (AEC) projects is an essential stake nowadays. Indeed many dysfunctions in construction projects are closely related to time, quality, human resources or cost management from a collective point of view. This paper addresses the issue of cooperation in AEC projects through the potential of the use of CSCW (Computer Supported Collaborative Work) support services.

Previous research works identify the coordination as one of the major aspects of cooperation. Addressing team coordination support through IT in AEC implies to take into account the specificities of the activity in this sector. These main characteristics have been underlined in (Kubicki et al., 2006a). They are related to the actors' organisations (i.e. short-lived and heterogeneous teams), the low-predictable nature of the activities, the "prototype" character of each building project and the flexible processes of document exchanges.

In this specific context we consider that today, coordination is essentially based on coordinator's know-how. Even though coordination missions have been officially defined in some countries, regulatory approaches do not sufficiently cover, at the present time, the human, methodological and technological aspects related to this activity. We introduced the concept of "cooperative engineering" in our previous research works to describe the specificities of construction coordination (Kubicki et al., 2006b). It is an activity where on the one hand actors are supervised by coordinators in a hierarchical way, i.e. related to classical approaches of coordination in organizations (Mintzberg, 1978). But on the other hand they also often proceed to an "auto-regulation" to accomplish their work in more "adhocratic" organization forms, i.e. allowing them to flexibly configure work processes to respond to their specific needs (Toffler, 1970). Such complementary hierarchical and auto-regulated approaches are performed in collective contexts where trust is necessary to enable cooperation between actors (Guerriero et al., 2008).

We state that IT technologies have to support these aspects of coordination: hierarchical coordination (closer to traditional project management), adhocratic coordination (by providing the actors with a comprehensive representation of their cooperation context) and trust-based reasoning (by providing contextual information necessary for the actor to build their own perception of trust degree in the activity). Through a "computer support" point of view we notice that:

- Existing IT tools (i.e. softwares) are often *"single business" oriented*. It means that they are designed to support the specific activities of a single building trade and do not really support AEC activities in their cooperative dimensions.
- These tools present a *lack of interoperability*. Problems related to exchanges of graphical representations of the building have been largely addressed by research and industry. We more specifically underline the issue of interoperability between information systems (Nitithamyong and Skibniewski, 2004) used in the organizations involved in a project and the lack of capacity to consolidate heterogeneous data related to the cooperative project.
- Finally these tools, when they support management tasks (e.g. planning tools), *only offer partial representations of the cooperation context to their users* (Kubicki et al., 2007). Moreover, these representations are often related to the classical information described in coordination documents (planning, meeting re-port, documents up-to-date lists...). This limitation restricts the capacity of actors to appreciate the state of project activity.

In this specific context our objective focuses on the design and appropriation of new software services to support cooperative activities in AEC. Cooperative tools used in other industrial fields have shown their limits when they have been applied to the building construction sector. It is due notably to their complexity and their irrelevance to the specificities identified above. Our basic hypothesis is that new tools supporting cooperation have to take into account these specificities. They also have to be able to be interfaced with existing tools in order to strengthen their usefulness for the users. Finally, appropriation by the end-users has to be taken into account in order to ensure that the practitioners will feel the value-added of the proposed services.

The article suggests making use of a generic Sustainable Service Innovation Process (called S2IP). After having described the overall S2IP approach (section 2.1) we suggest to apply its first process of *service value* identification to our case study related to document management in AEC (section 2.2).

Section 3 details the service design methodology and its aspects related to requirements gathering (3.1), appropriation monitoring (3.2), best practices identification (3.3). A shared model of AEC cooperative activity is depicted in section (3.4). It could be a way to achieve interoperability between heterogeneous and single-business specific tools.

Then the designed business services are presented (4.1) as well as the development of a prototype (4.2) implementing them.

Section 5 presents validation aspects of our proposition. It describes the projects in which the business services are used (5.1) and the results of end-users appropriation monitoring (5.2). Even though experiments are still in progress, early conclusions are depicted (5.3).

Finally this work related to AEC-specific business service design lets us discuss some prospects. We distinguish between prospects about document exchange support in AEC projects (6.1), prospects in order to make our business services sustainable at national and international level (6.2) and prospects about service modelling and business alignment targeted in a starting research project (6.3).

2. SERVICE-BASED INNOVATION APPLIED TO THE AEC INDUSTRY

2.1 Towards a Sustainable Service Innovation Process (S2IP)

Innovation in services is a crucial point in the economical competitiveness of enterprises and especially SMEs that mainly represent the AEC industry firms (European_Commision, 2006). In this first section, we would like to present how the design and the validation of these services are part of a general process applied by CRPHT (Public Research Centre Henri Tudor) in a rigorous management of its innovation activities.

CRPHT is the Luxembourg R&D centre dedicated to the support of technology transfer and innovation in different technological domains including ICT, health, environment and materials. In the ICT domain, most of these applications are services oriented. This is in line with the nature of the national economy where the service sector accounts for above 85% percent of total value added in 2006 granting Luxembourg with the first place in the European landscape. According to the EARTO terminology (www.earto.org), CRPHT is an RTO, a public Research and Technology Organization whose is a "specialized knowledge organization dedicated to the development and transfer of science and technology to the benefit of the economy and society". The main mission of an RTO is therefore to provide research, development and innovation services both to private and public beneficiaries according to an open approach (or Public-Private-Partnership) where it acts as interface between universities and firms (Dodgson et al., 2005).

In order to perform its public mission, transfer of technologies but also of knowledge, ideas and concepts, CRPHT has defined and applied an innovation management process targeting the support to innovation in services within open partnerships with the targeted beneficiaries (Chesbrough, 2003). This process is called "Sustainable Service Innovation Process" (S2IP) (Absil et al., 2008). It is based on a participatory and collaborative innovation approach in order to sustain deep involvement of the network's actors in the development of innovation services. Targeted services are mostly based on ICT services but packaged into business services, i.e. also including the organizational (processes) and the human (skills and competencies) perspectives. This view is in line with the new research domain of Service Science (Chesbrough and Spohrer, 2006). The overall structure of S2IP is depicted in FIG. 1.

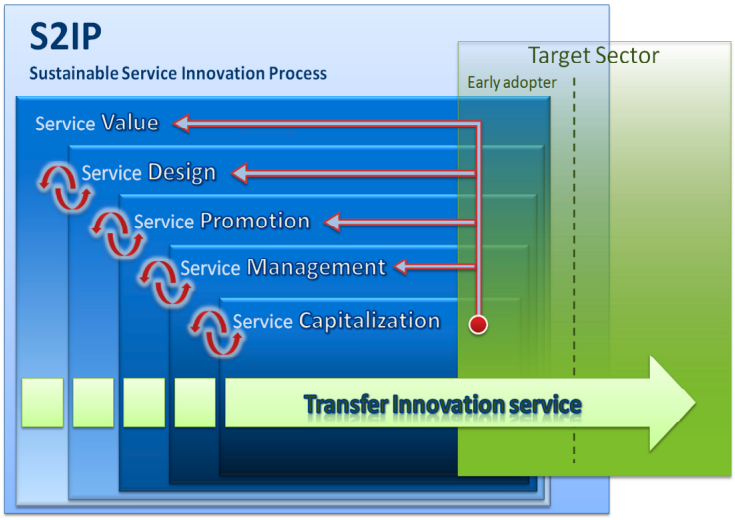

FIG. 1: The S2IP Innovation Process

Although the figure may suggest that the S2IP is lifecycle oriented, the reality is that each box corresponds to a process that has to be performed and may be pursued in parallel with other processes in a non strict sequence.

The main processes are:

- *Service value* and business strategy: This process covers the activities associated with the identification of an opportunity for a new service innovation. They cover a study of the

technological feasibility of the service (which, in most cases, requires the building of a demonstrator for the purpose of experimentations with early-adopters) as well as a preliminary identification of the business model associated with the value proposition (both expressed in terms of tangible financial elements and of intangible assets).

- *Service design* and engineering: This process is associated with the definition of the service not only in terms of its business functional objectives but also in terms of all its required (non-functional) qualities. This requires eliciting the strategic goals of the different early-adopters stakeholders involved in the final acceptance of the service as well as to understand the constraints associated with the environment (like specific regulations associated with a sector). From this initial elicitation, requirements have to be formally expressed in terms of properties of the services that can be organized in terms of a service contract (or a service level agreement).
- *Service promotion*: Once the service contract has been validated by early adopters, it is important to promote the service to other potentially interested parties. This can be done within an organization through some marketing regarding the socio-economical sustainability of the service. In a network of organizations or for a sector, this promotion can also include initiatives regarding the branding of the new service through some label definition and associated certification scheme. Ultimately standardization activities run for example at the national or international levels (like e.g. ISO) definitively help in a successful promotion of the service.
- *Service management*: It is out of the scope of CRPHT's mission to deploy by itself the service with an organization or within a sector. This is where the market should play its role. However we define and provide tools that can be used by those that will deploy the service for checking and measuring the correctness of its implementation. In particular for each new service we propose metrics associated with the measurement of the quality of the services implementation with respect to the services contract.
- *Service capitalization*: Once a services system is deployed within organizations, we can start to collect the feedback associated with the measures as well as from assessment performed with the end-users. The analysis of this feedback indicates the possible evolution of the service in terms of new requirements, new business models, etc. Thus this is where new iterations associated with the different processes described above are starting.

2.2 Applying the S2IP Value Proposition Process to the Building Construction Sector

Starting from the generic presentation of the S2IP introduced above, we now illustrate its application to our business case in the construction sector by first considering the initial *Service Value process*. The *Service Design process* (box #2) is the main focus of sections 3, 4 & 5 of the paper. The three other processes are under progress and then we will describe them as prospects in section 6.2.

The *Service Value process* has the twofold objective of "inventing" new services together the strategic business model underlying their acceptance and sustainability. The invention itself is difficult to formally describe but it always results from the matching between the knowledge about an innovation opportunity in a sector or a firm, and the knowledge acquired about the potentialities of new technologies, new processes, new methods, etc. In our case, knowledge about the sector was gained through our long-term partnership with the CRTI-B (the national professional association promoting new usages of ICT in the construction sector, http://www.crtib.lu) in Luxembourg. Working groups and brainstorming sessions were conducted with representative members of CRTI-B (engineers, architects, owners, facility managers, contractors and also local software vendors) at the beginning of the Build-IT project (a national-funded research project)(Absil et al., 2008). Moreover knowledge about technology and scientific advances was acquired through our parallel (and past) research activities and cooperation with European universities and R&D institutions.

As a result of this initial strategic stage specific needs have been identified to improve cooperative processes related to 1) building construction management and 2) project document exchange. Build-IT project addressed initially (2004-2007) the issue of building construction management through IT-supported meeting report writing and diffusion. The development and experiment of a Web tool is reported in (Kubicki et al., 2006b). A second stage in the Build-IT project has targeted the document exchange processes in construction projects (from 2007 to now). We have begun by identifying with practitioners the limits of the actual use of project platform for document sharing. The results have been very interesting. Practitioners themselves found that cooperative practices have to be agreed and strengthened (they called it the "human side" of the problem), even though technology has to better fit their needs and projects' specificities (i.e. the IT side).

This conclusion is reinforced by a review of literature on the topic of technology appropriation factors applied to IT innovation in construction. Obviously research works describe the factors of success or failure in the adoption of IT technologies in construction projects through the usefulness of the systems' functionalities and their alignment with business needs (Nitithamyong and Skibniewski, 2004). But besides technology, we notice that organizational (Alshawi, 2007) and psychological factors (Tatari et al., 2004, Hjelt and Bjork, 2006) have to be considered. In such approaches the user's perception is essential, and literature suggests two major dimensions of the perception of a system: "perceived usefulness" and "perceive easy of use" (Davis, 1989). Training of human resources is also a major issue and interesting works suggest basing the trainings on realistic task-based working scenarios (Rezgui et al., 2004).

The section 3 of this paper addresses the *service design process* performed to propose both cooperative best (human) practices for the sharing of documents and related business services implemented in a Web-based software service.

3. AEC-SPECIFIC SERVICE DESIGN METHODOLOGY

This section develops the methodology of *business service design* applied to document management practices. We first develop the process related to the identification of specific requirements of our professional partners (3.1). Then we describe how the end-users appropriation has been addressed (3.2). The seven best cooperative practices are exposed in detail (3.3) and finally the model-driven engineering approach used to implement the IT services is presented (3.4).

3.1 Document management and CRTI-B requirements

At the centre of our innovation idea was the decision to address the issue of document management through two viewpoints: the human one (i.e. human practices related to document exchanges) and the technological one (i.e. existing software solutions and development of new software solutions).

Construction projects are considered as weakly integrated cooperative activities and further as low-replicable processes. That is why the issue of document management needs to focus on the structuring of metadata related to these documents (Caldas and Soibelman, 2003, Forcada et al., 2007) and their indexing related processes (Whetherill et al., 2002, Barresi et al., 2008) rather than on cross-organizational workflows approaches. A recurrent topic is the management of metadata. It should be considered through both the human viewpoint (Why do I share a document? How to document the flow of documents?) and the technological one (How to represent metadata, in terms of semantics? How should the users fill in metadata, e.g. in terms of work overcharge?). Regarding such approach, it should be noted that Turk & Björk suggested one of the first models describing document-related concepts in AEC: presentation, document lifecycle, organization and especially the link with building product models (Turk and Björk, 1994), whose implementation is the focus of numerous research work today.

In this context, designing new document management services for the AEC sector is not really challenging but designing those which really answer to the demand of the CRTI-B is really the topic of the innovation. Moreover identifying best cooperative practices related to document management is part of CRPHT and CRTI-B 's public mission towards improvement of the AEC sector competitiveness. To do so the following activities were performed with the overall objective of demonstrating the existence of a business model (further detailed in Section 6.2) for new software services. Such a business model fits a clearly identified market and reinforces business cooperation and competitiveness in the construction industry.

- During the first activity, surveys were performed and showed that most of the users were not really satisfied with the existing software solutions they used. Some reasons were collected through brainstorming sessions with practitioners. Interesting synthesis papers also introduced some metrics and indicators to understand the factors of success or failure of AEC groupware solutions (Nitithamyong and Skibniewski, 2004, Nitithamyong and Skibniewski, 2007). The complexity of their common functionalities and associated services is one important reason (Björk, 2002). Their low alignment to the AEC projects specificities (in particular organizational, processes and actors' skills ones) appeared as another reason of the failures in introducing such new IT information systems. Finally technical reasons also were underlined. Actors have to use numerous IT solutions (i.e. one project – one tool) because it is often that the owner or main contractor decides and forces to use such a system in the project.
- Then, as the decision was taken regarding the development of a new solution, initial needs were formulated by the end-users themselves through an survey/interview stage. Working practices and

behaviours were collected by CRPHT who transformed them into a comprehensible set of "best cooperative practices". Dedicated working groups then permitted the practitioners to debate and finally agree on standardized best practices in a consensus way. We underline here that it is the role of the CRTI-B as a multi-trades representative body to standardize practices in a consensus methodology. This is sometimes hard to achieve and certainly takes time but this is necessary to ensure a mutual agreement of diverse practitioners on cooperative practices involving every one of them.

- During the third activity, six releases of the software demonstrator were incrementally developed and regularly validated with 6 working groups. These working groups were constituted of approximately 15 AEC practitioners representing several fields of activity (i.e. architects/engineers, owners, contractors). The CRPHT team frequently presented the business services developments' progress. This enabled a validation of the progress but also an early appropriation of the software application by its future users.

Experiments have begun early with only some basic business services in order to rapidly debug the IT system and also to encourage the users to better formulate their needs.

3.2 Monitoring end-users appropriation

The appropriation of the new software has been an issue for the project team all along the design process. We here consider appropriation as a process in which the user makes the tool his own, and which, starting with the first mental representations of the tool, unfolds long after the first routines of use have appeared (De Vaujany, 2005). The process of appropriation is linked to the knowledge that the individual has of it; the tool becomes an object of knowledge as the users gets to know it better.

The process of appropriation has three dimensions (Dumont et al., 2008):

1) On the one hand, the "technical" appropriation refers to a co-adaptation, in which the users adapt the tool to their frequent uses and adapt themselves to the characteristics of the new tool and to the norms embedded in it.
2) On the other hand the "social" dimension of appropriation focuses on the users as individuals, social actors whose behaviours are regulated by social norms. The tool is s a social construction, not only physically developed by humans but also socially built, as they grant it some sense (Orlikowski, 2009). The appropriation of a tool is therefore impacted by the specific context which it comes in and by the individual objectives of the actors.
3) Finally appropriation also has a "managerial" dimension as the role of coordination in AEC projects is determining. Exchanges between the different actors of the project enables each of them to understand how important it is for the others, favouring motivation and trust.

Wishing to monitor the appropriation process very closely, we decided to build a scorecard, which would 1) measure the level of appropriation, and 2) help us to manage it (take corrective actions in case of poor results), and communicate with actors by showing the added-value of our business services on cooperation practices in AEC projects.

In a constructivist approach, we do not consider the scorecard a decision-making support-tool only (Fernandez, 2005) deployed on the late stage of implementing a strategy, but we consider its construction to strengthen the definition and emergence of the strategy as an ongoing and iterative process. Through the collaborative elaboration of the scorecard, the project team defines its objectives and fine-tunes their expectations in terms of appropriation.

Drawing on the above-described dimensions of appropriation we structured our reflexion in four dimensions (Dumont et al., 2008):

- Technical object: Do the functionalities of the tool meet the users' requirements?
- Users: How do users use the different functionalities? How do they perceive the software service?
- Social-technical network: How widely spread is the software service? How do actors interact around it?
- Cooperation practices: How does the use of the tool impact cooperation practices in AEC projects?

The project team built the indicators, following the recommendations of the AFNOR FD-X 50471 norm.

- A first participative session gathering the project team consisted in identifying criteria of appropriation in each of the four dimensions, i.e. factors hindering or fostering appropriation. Then parameters were associated to each criteria, i.e. how would the criteria be assessed, i.e. a means to quantify or qualify the criteria. The parameters would be the data composing the formulae of the indicator. This was achieved though a "post-it brainstorming session" where all participants wrote down their ideas on post-it notes, shared their suggestions and discussed them. 12 criteria of appropriation emerged from this session. From these discussions emerged a common understanding of the appropriation of the software service.
- In a second session, the project team jointly validated the criteria and parameters and, on this basis, jointly built the indicators. The main discussion emerged during setting the appropriation thresholds: when do we consider appropriation to be achieved or not? It contributed to fine-tuning the vision of appropriation. Another crucial point of indicators building lies in setting how the parameters will be collected: the project team members become more deeply involved in the strategic management process when they realize what it takes to feed the scorecard.

Finally the scorecard itself was constructed using MS Excel. Indicators are calculated automatically when parameters are uploaded in a specific sheet.

Integrating the elaboration of the scorecard in the design process itself has enabled the project team to develop a shared and structured vision of their objectives in terms of appropriation. It has raised their awareness toward the accompaniment actions to foster the appropriation of users.

The scorecard is used today to manage the appropriation of the software service during the testing period (see section 5).

3.3 Best practices identification

The best practices related to document exchange processes were identified with the practitioners through a global survey and 8 long interviews with 2 architect offices, 3 engineering agencies, 1 contractor and 1 public owner. During the preliminary survey stage we discovered numerous internal document management methods. Our work then consisted in extracting the high-level practices, i.e. the common denominator, on which everyone could agree. They were finally discussed, agreed and validated during 3 CRTI-B working groups.

The resulting best practices are described below, in simple terms. They should be applied in specific project setup situations, in totality or partially:

1) A common structuring of project documents is defined (P1).
2) A standard naming of project documents is setup and agreed by all the actors involved (P2). In Luxembourg the OAI has developed a standard name norm, which is notably used in public buildings projects.
3) Modifications are described and localized on new releases of documents (indexes) (P3).
4) When a document is shared, it is necessary to inform the interested participants of its availability (P4), i.e. a document is always shared for a good reason.
5) Requests between project's participants have to be recorded in order to manage it (P5).
6) Interactions and reactions about a document between participants have to be recorded (P6).
7) Privacy areas for document sharing are defined (P7).

These practices appear simple and common. However, defining and applying them in project situations is not so easy. Very often a coordinator should be in charge of verifying and sensitizing the participants to them. Of course, IT supports the realization of these cooperation practices (CSCW, groupware tools). But in numerous cases we observed that tools are too complex and not adapted to the AEC specific activities. Then the users are confronted with practical problems in their document exchanges and retrievals. They loose time and, as a consequence, do not take much effort to improve their practices.

This assessment lets us to propose a prototype tool "CRTI-weB Document Management" implementing these basic best practices into related business services (section 4.1).

3.4 A model-driven approach

3.4.1 Modelling the business context

This approach is based on model development, steering both domain analysis and tool engineering. It is largely based on Model Driven Architecture (MDA) for software systems development (Soley and OMG, 2000) where the objective is to define a framework of certified industrial standards (MOF, UML). In parallel, the Model Driven Engineering (MDE) research area is an evolution aiming to unify different technical spaces (XML, ontology etc.). It does not focus on a unique technology: it is an integrative approach (Bézivin, 2005). MDE recommends the use of meta-models to define domain languages. Models represent real systems. Each model has to be conformed to its meta-model (Favre, 2004, Frankel, 2003). Finally the transformation concept is a central one, a transformation being itself described with a model.

We use this methodological framework and suggest two levels of modelling for the cooperative activity in the AEC domain (Kubicki et al., 2006a). A Cooperation Context Meta-Model (CCMM) allows us to describe the cooperative activity at a high level of abstraction. This meta-model is used to construct a specific model representing the particular context of a real construction project. The instantiation MOF architecture (M2 > M1 > M0), which we base this reasoning on, nicely fits in with the approach based on models and meta-models from MDE.

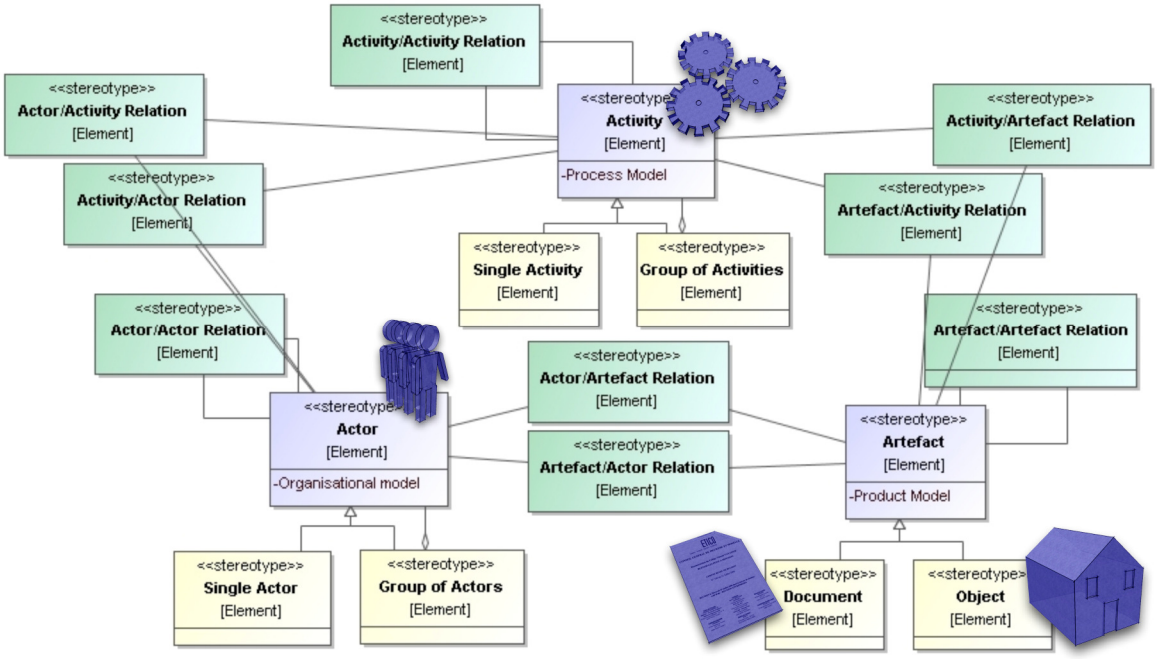

FIG. 2: Cooperation Context Meta-Model CCMM - M2 (extract)

Our CCMM (M2) takes into account the existing relations between the different elements of a project (See FIG. 2). We identify three main categories of elements existing in every cooperation project: the activity, the actor and the artefact (associated with documents and objects related to an activity). CCMM strengthens the relationships existing between these elements of cooperation.

More details about the CCMM can be found in articles where we have instantiated M1 models to represent specific architectural design contexts (Hanser, 2003) and building construction activity dedicated contexts (Kubicki et al., 2006a). At the lowest abstraction level, these Cooperation Context Models (CCM, M1) also enable the description of particular project contexts (M0) representing the business knowledge corresponding to a real project. We emphasize also that an additional benefit of having several M1 models instantiated from the same M2 is to guarantee a better interoperability between different information systems possibly located in different organizations (e.g. engineering offices, architectural agencies, public owners…).

Until now, this model-driven framework especially led us to define two coordination-specific visualization tools:

- Bat'iViews: a multi-views interface enabling contextual navigation in AEC-traditional views (Kubicki et al., 2007).

- Bat'iTrust: a dashboard view based on the concept of trust in the good progression of the construction activity (Guerriero et al., 2008).

In these works the objectives were to suggest new visualization modes based on a credible source of information. However, coordination of the AEC activities relies on information scattered among multiple sources. We can notice that:

- Numerous documents are produced and used. There is a risk of redundancy and incoherence between them.
- Information sources are not centralized, they are often hosted internally by the actors producing it.

Then the suggested modelling framework enables a theoretical definition of the cooperation context and leads us to perform prospective research works on this basis. This rigorous domain modelling approach also opens connections with other data sources managed on the basis of other ontology definitions such as IFC model servers, or tools based on the AEC-specific e-cognos ontology (http://e-cognos.cstb.fr/).

3.4.2 Cooperation context and services

The applied research that we carry out in the framework of the Build-IT project at the CRP Henri Tudor is oriented towards the specification and implementation of cooperative software services for the building construction sector in Luxembourg. In this context the theoretical research about domain modelling (AEC cooperation context) has become the basis of our developments. The model of the cooperation context (§3.4.1) has been enlarged in order to fit the needs of our developments. It is the basic information model allowing us to describe the AEC-specific concepts manipulated by the users through the "CRTI-weB software services".

At this step we would like to clear the use of the following terms: software service, business service and Web service, which enable IT-supported management of cooperation context described before (see FIG. 3):

- We refer to *software service* to describe IT application that are used by AEC practitioners. More specifically in our approach we use this term to refer to SOA-oriented applications provided through Internet by the use of "thin clients" (usable with simple Web browsers). This definition is closer to the one of "Software-as-a-Service" where "an application is hosted as a service provided to customers across the Internet" (Bennett et al., 2000, Sun et al., 2007).
- From our point of view *business services* are core elements of software services. Following (Papazoglou and Georgakopoulos, 2003) business services are "self-describing, open components that support rapid, low-cost composition of distributed applications [i.e. our software services]". They support business processes (e.g. related to cooperation context working practices), have both functional and non-functional aspects and configuration capabilities, in the sense of service composition and reuse.
- Finally *web services* are well known and discussed. At technical level Web service is "a specific kind of service that is identified by a URI, whose service description and transport utilize open Internet standards" (Papazoglou and Georgakopoulos, 2003). Main characteristics are their declarative service description and automatic service discovery (Curbera et al., 2003). One major issue related to Web services is their composition capability "in the form of business processes" (Peltz, 2003).

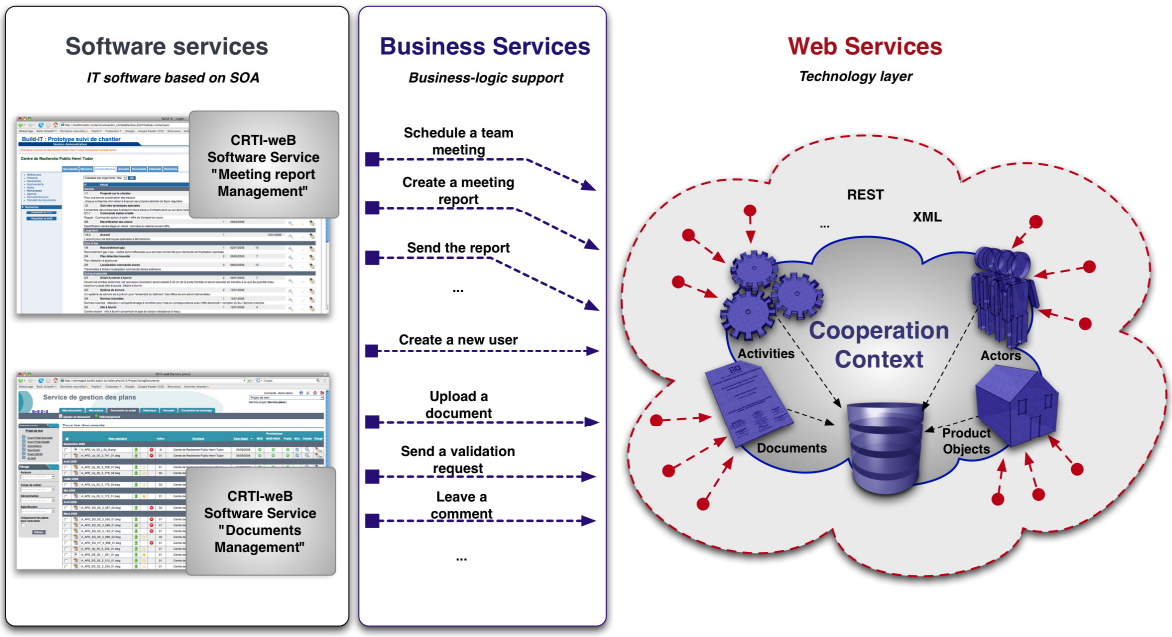

FIG. 3: Services managing cooperation context

4. CRTI-WEB BUSINESS SERVICES FOR DOCUMENT MANAGEMENT

A first set of business services has been developed previously to support meeting report writing and diffusion (Kubicki et al., 2006b). We present here the second set of business services dedicated to document exchange management, supporting the best working practices described before (section 3.3).

4.1 Business services presentation

From the identified cooperation practices (P*x*) related to document exchange processes between AEC practitioners, the following business services have been incrementally developed:

- P1, P2 & P3. A *file name management business service* enables the use of a standard for naming the plans, contracts or meeting reports. It is defined for each construction project and allows obtaining the metadata of a document when it is uploaded. It also ensures the classification of documents in the standard structuring of the project. Standard name is composed of fields and separators. A web service parses the name of the document submitted by the user and interprets its content. If the user uses standard names for his documents, he has just to check whether the name is correct or not. If the name is not correct, he can rename his file using the form that the tool suggests.
- P4. A *notification business service* allows the users to receive a notification when a document is uploaded, updated, or when various actions are performed (such as leaving a reaction, assigning a request and so on). For example an engineer designing his plan on the basis of the architect's one is automatically informed of the upload of a new architect's index, which could be of interest for him.
- P5. A *request management business service* has been developed to manage and keep track of the interactions between the users. The author of a document can inform someone else that a document has been uploaded. He can also make a request for validation or ask for a reaction. Requests, "due date" and "accomplished date" are then stored and enable to track the state of a document (validated, waiting for a validation, rejected).
- P6. The *reaction business service* tracks the discussions between users about a document and allows them, for example, to inform the owner of a change immediately.
- P7. Finally, a *privacy management business service* allows managing privacy areas in which the users are authorized to access or not: a first area is restricted to the designers (architects, engineers), a second one allows the owner to see the plans he has to validate, and a third one is completely public and accessible for all contractors.

These business services have been implemented in a Web-based software service called “CRTI-weB Document Management”. A demonstration access is available at http://demoged.buildit.tudor.lu (login: “demo”, password: “demo”)

FIG. 4 shows the main business services of this tool which are associated to the list of the project’s documents. The user could navigate in the documents through a hierarchy (see extract #1 on the picture) based on the main stages of the AEC project, which can be differently defined for each project (related to P1: structuring of documents). Project stages are part of the standard filename defined for a project. The extract #2 shows how the standard named documents appear in the list. When the mouse is moved over the file name, indication comment field appears and displays the detail of the document’s name (see extract #3). Finally the extract #4 shows how the three privacy areas are visualized for each document. The figure also presents the filtering possibilities for the user in case he has to find a particular document in the database. Filtering is based on standard name metadata.

FIG. 5 presents a view detailing a document shared with the tool. The first table (extract #4) shows the different document’s indexes and the details of their modifications. This business service is related to P3 and encourages users to precisely specify what are the changes on the different indexes. Each index of a document can ever be downloaded. Extract #5 shows the reactions on a specific document (P6, each user can leave a comment on a document, such as on a forum). Finally, extract #7 details the requests that are linked to the document. For each validation or reaction request, due date and accomplished date are also displayed allowing anyone to know whether concerned users agree the document.

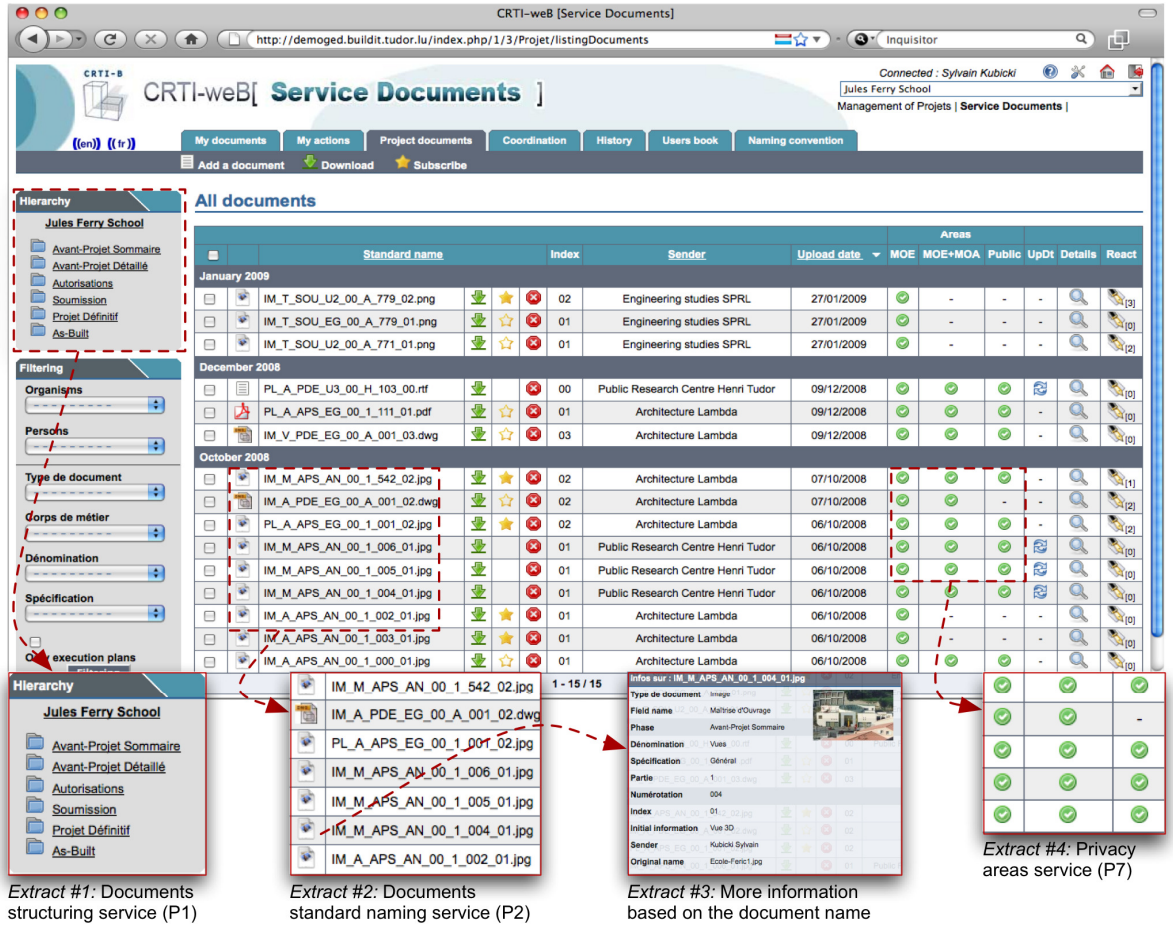

FIG. 4: CRTI-weB main interface presenting a list of project's documents

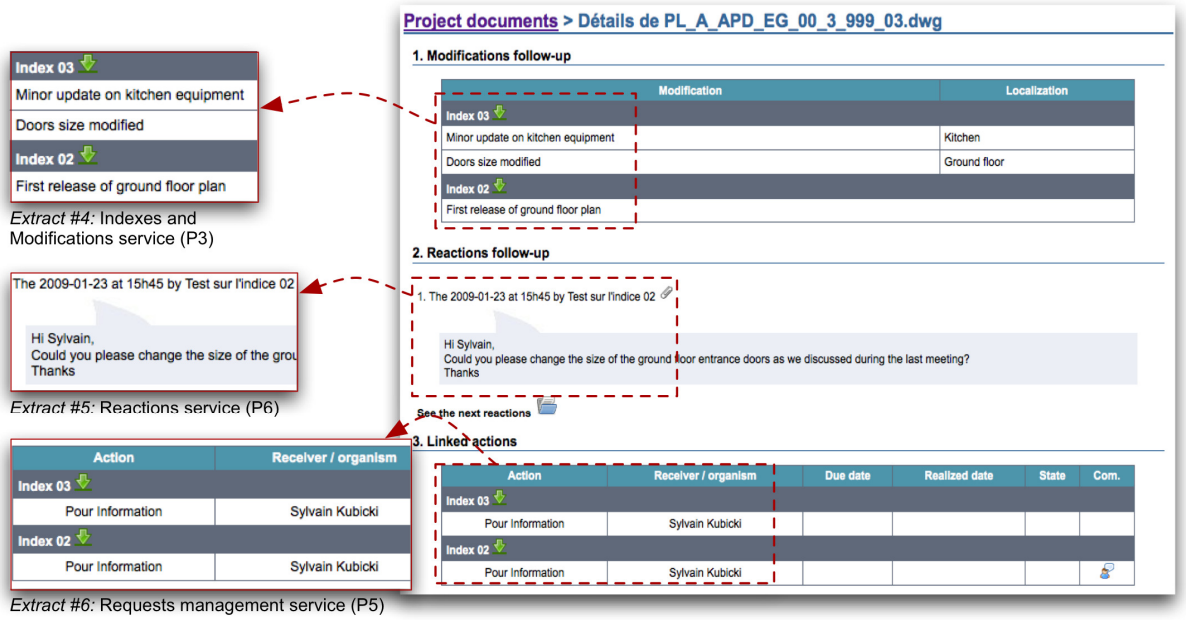

FIG. 5: Details of a shared document

4.2 Development of a prototype

Today most of the solutions are based on a classical client/server architecture enabling the description, storage and retrieval of project data (i.e. cooperation context) in a database. Examples of such systems include the solution developed in the ISTforCE EU project (Katranuschkov et al., 2001) and the one which is targeted in the e-Nvision project (Angulo et al., 2006). In our case, for the purpose of openness and ease of integration with existing tools, we chose to orient our developments towards a service-based architecture.

Our business services' platform manages the cooperation context, based on a specific construction business-domain model instantiated from the cooperation context meta-model CCMM) presented in section 3.4.1. Following the Model-Driven Engineering approach, we have built a specific cooperation context (M1) associated with the work practices described in the previous sub-section and derived from CCMM (see right part of FIG. 6). This modelling framework enables to define an adaptable and flexible business context, which was useful in the incremental development of the different demonstrator's releases. The suggested extract of the M1 model represents the context of specific design/construction activities characterized by many exchanges of documents (plans, 3D views, texts) between different actors (firms, agencies, control bodies, etc.). For example, in the M1, we can explicitly manage the relationships between the author of a document (e.g. a plan) and the other actors who have to validate it.

The implementation of the business domain context through the use of business services requires using the same modelling framework to guarantee the alignment between the concepts introduced at each modelling level. The Business Service meta-model (left part of FIG. 6) describes existing visualization modes, designed business processes, usable functional resources and the necessary configuration elements. The "metaconcept matching" at M2 level enables to define Business Services adapted to specific Business Cooperation Contexts by matching business concepts when configuring the business service (M1 level).

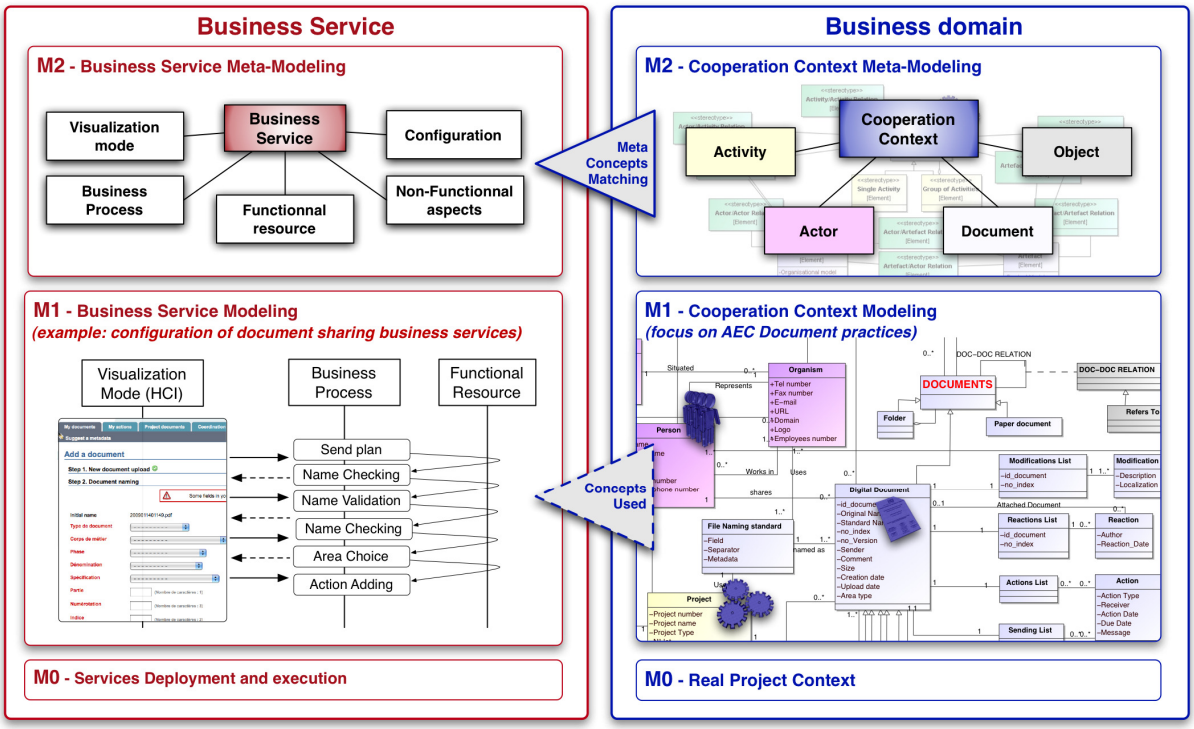

FIG. 6: A MDE approach for the design of IT services fitting a Business Domain.

The Business Services described in the previous section have been technically implemented through the use of Web services. The aim is to facilitate their integration into existing software infrastructures used by some of our AEC industry partners. These Web services are described in the REST protocol (Fielding, 2000) and are also available in SOAP (which is most common). REST is a Web services technology based on the Web architecture and its basic technologies: HTTP, URI and XML. We structured these Web services using the ROA approach (Resource Oriented Architecture) (Richardson and Ruby, 2007). It describes a set of good practices for REST Web service design and is strongly adapted to our Agile development process, involving business experts, technical experts and final users.

5. EXPERIMENT

The experiment stage is a major part of the *service design process* (box #2 of the S2IP, see FIG. 1). One essential challenge the design of innovative services for the AEC industry has to face is the one of appropriation by the future service end-users.

5.1 Context

As described in the previous section we designed business services based on the identification of best working practices. These business services were then implemented in a Web-based software service called CRTI-weB "Document Management". The object of the experiment stage is to use this software service in real project contexts. Both the alignment of business services to the practices and the usability of the software service were assessed during experiments. The appropriation scorecard (see section 3.2) helped us to manage this activity. Indicators allowed the Build-IT team to pilot the experiments related to the four dimensions of appropriation: technical object, users, socio-technical network and cooperation practices diffusion.

The experiment stage has begun in September 2008 and is still in progress. In the following sections we distinguish between 4 "pedagogical" experiments and 3 professional experiments.

- On one hand, 4 experimental projects of architectural design were conducted with user groups composed of both French and Belgium students. In the "Cooperative Digital Studio" Master course (Kubicki et al., 2008), 21 students used the document management software service to share plans, sketches, photos and so on between Liège (B) and Nancy (F) during 8 weeks.
- On the other hand 3 real professional projects started in September 2008 and are still in progress (a fourth one has started in January 2009). 24 practitioners use the software service in these projects: kindergarten, primary school and restaurant (the fourth project is a hotel complex).

Each experiment begins with an informal contact between the support team (both composed of domain experts and technical experts from CRPHT) and one actor who decides to use the software service in the project (very often the architect). Then a formal team meeting allows us to describe the best cooperative practices to achieve in the project and the software service that will support them. Practices are generally debated between the actors (how to name the documents? How to track the requests?…) and the way of using the software service is agreed by all of them. A quality guide is finally distributed. It describes the best practices, and contains a simplified user manual.

5.2 Results

The support team uses the appropriation scorecard to pilot the experiment stage. We suggest to present here the first results of our experiments through the four dimensions that it manages.

5.2.1 Technical object

The aim related to the technical object dimension was to monitor the number of bugs' progression and the delay needed to correct them. We believe that this technical dimension is important because bugs prevent the use of the service, and decrease the level of trust of the user. As a result, since September the number of new bugs decreased and the period of time for their correction was respected (never more than 3 days).

5.2.2 Users

In this dimension we consolidated more qualitative data about the real use of the business services implemented in the software and about the particular way they are used. We distinguish between the practitioners' results (related to professional projects) and the students' ones (i.e. educational projects). FIG. 7 shows the cumulative number of documents shared during the experimental projects.

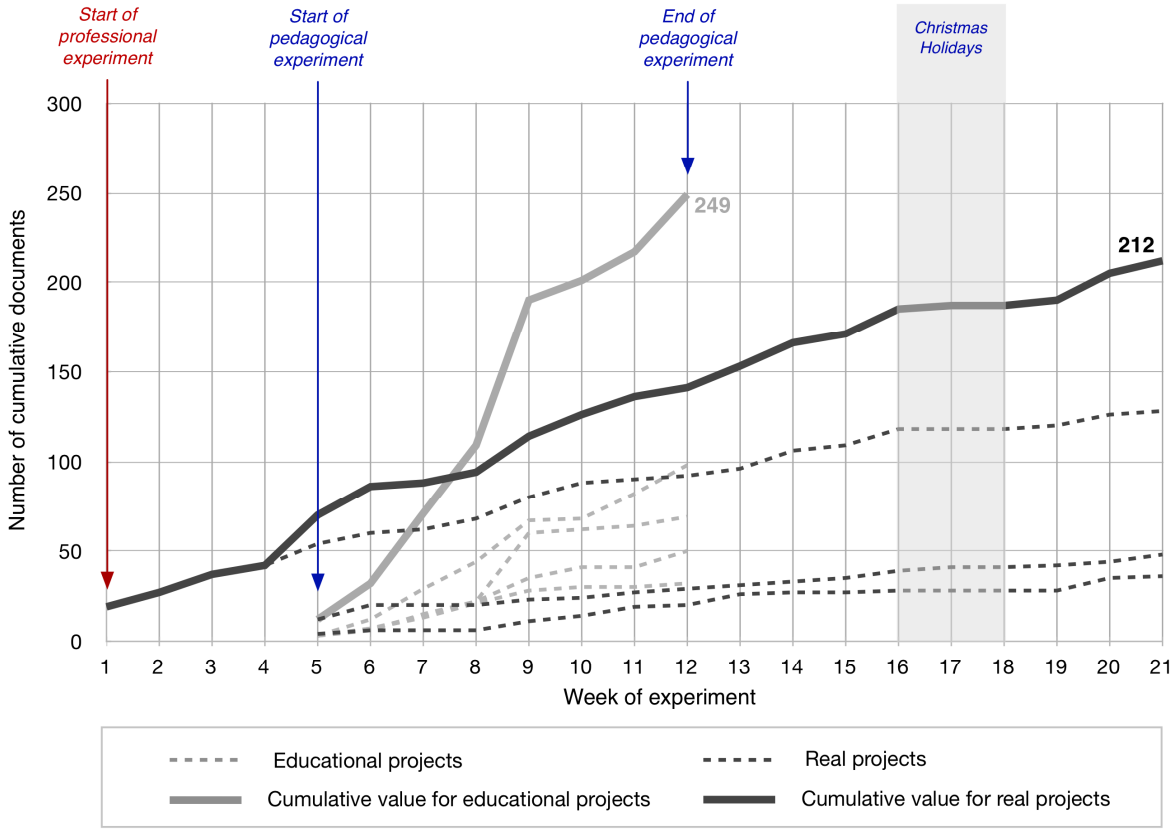

FIG. 7: Statistics of CRTI-weB use. Number of documents per experiment's weeks

On one hand we can notice that globally the practitioners (see "real projects" in FIG. 7) use all of the business services (probably because their number is voluntarily limited to fit the seven best practices). But the use of some "advanced business services" (such as reaction service and privacy areas management service) is not a fact for all the 24 users. Only a few early adopters use these innovative services and seem satisfied of them.

We plan also to collect more qualitative data at the end of the experiment stage. During interviews we will ask the users about perceived usefulness of the business services, about usability of the software service, and we will

try to collect how they think the software improved the quality of exchange processes, the tracking of documents and interactions, and in which way using the business service saved time in the project.

On the other hand, we assess that educational projects do not widely make use of the document management business services designed. As we can see in FIG. 7 the software service is used by the students to share numerous documents. But a fine analysis of each business service's use shows that some of them are too much "advanced" to be used in educational project contexts. This is the case, for example, for the "privacy management" business service, which is not useful when only designers are involved in a project. Some aspects of the "filename management" business service are also not used, such as the management of multiple releases (indexes) of a document, which is not adapted to early design situations (i.e. documents are not "sustainable" and therefore are rarely updated).

Business services are not all used by students, but in a pedagogical approach we believe that using such a professional software service allows them to discover useful business services, and then to sensitize them to cooperative best practices. Students are also very prolific in giving us prospective improvement ideas, such as designing chat and forum business services or enabling multi-projects document sharing.

5.2.3 Social-technical network

This dimension targets how the actors network around the software service. One major point consists in appreciating the representativeness of the actors involved in experiments. We believe that experimental users have to represent most of the building sector profiles (owners, designers: engineers/architects and contractors) in order the appropriation be higher. In our case all profiles are represented. But we notice that designers (engineers and architects) are most involved in new demands and business service improvements.

5.2.4 Cooperation practices

Beyond validating the services, the experimental stage also aims to disseminate best cooperative practices in the building construction sector. The appropriation scorecard also monitors how the use of the software service helps to diffuse the best practices in the sector. This is a long-term prospect, and we will try to assess how many participating organizations adopted best practices, and whether they plan to implement them after this test period. This dimension will be assessed in a final survey.

5.3 Experiment conclusion

Experiments are still in progress, and a final survey will give us more qualitative information about perceived usefulness and usability of the software service. After 5 months of use we can globally validate the usefulness of the business services designed. Moreover, we can highlight three particular conclusions:

- In each project we notice that the use of "advanced business services" is regularly increasing. Only a few early adopters begin to use them and boost these services by promoting them to the others. However, we will confirm this point in final survey, which will allow us to gather more qualitative feedback to really validate it.
- We also underline that the setup stage is essential in these experiments. The first team meeting is determinant, and all the participants have to agree on the use of common cooperative practices and related business services. A federated team approach is clearly a key factor of success.
- Some technical limits identified in the *service value design* stage are still remaining, such as the multiplication of project platforms or the important time lost in waiting for upload/download transfers… This lets us to suggest some improvement prospects in section 6.1.

Another conclusion is related to the two different contexts of use: the educational one vs. the professional one. In the future months we plan to develop two versions of the document management software service implementing dedicated business services to better fit these two contexts:

- The educational version with more prospective business services, adapted to unstable and flexible working processes (i.e. early design stages),
- The professional version with business services supporting more standardized exchange processes and highly contract-based contexts.

6. PROSPECTS

The methodology of AEC-specific service design applied to the particular issue of document management lets us present some prospects for our future work. We organize them into three sub-sections: prospects related to the

specific issue of document exchange support in AEC (section 6.1), prospects related to our methodology (especially the aspects related to the sustainability of innovative services)(section 6.2) and finally prospects about service modelling targeting the issue of alignment between service offer and business context (section 6.3).

6.1 About document exchange support

The approach of document sharing in AEC projects is closer to the one related to internal processes management (e.g. quality/ISO certification). During our specification stage we underlined the problems related to management of documents inside the organizations and we noticed the various levels of maturity of such working practices. Then we tried to identify the related "internal best practices" (vs. best cooperative practices at the core of this paper), such as managing documents on a file server, uploading/downloading documents from a project platform, storing modifications lists on document releases, managing internal requests between project team members and so on. We have already specified the support business services, which could help to improve these internal practices. We are now developing a prototype of an "internal client" software service implementing it. Through this development we aim both 1) to improve internal practices and 2) to foster the use of the cooperative project software services CRTI-weB through document synchronization mechanisms and simplified forms.

The document exchange issue is the second research axis of the Build-IT project. This project addresses specific development of cooperation support services and also aims to accompany the Luxembourg construction sector towards electronic cooperation and in the future, towards Building Information Modelling. The second prospect, in this context, aims at progressively introducing the link between today's tools and future tools based on digital modelling of building (BIM). In the document management software service, we introduced this link through references to building elements. When, for example, a user describes a modification made on a document, he is required to fill in the "localization" field. For us, this is a first step towards the integration of document oriented systems and product oriented systems (Turk and Björk, 1994, Rezgui and Cooper, 1998), aiming to sensitize the users to the need of better documenting the exchanges, and to the upcoming benefits of BIM.

A third important prospect is related to the transfer of project content from an EDM to another. In fact, many project collaboration solutions exist on the market. Everyone agrees to say that one major limit of the appropriation of such tools by the end-users is that they often have to use (and to adapt to) one tool for one project. Moreover there is a real issue related to project data archiving (Moses et al., 2008), especially when data is stored by an external provider. We envisage to address this issue through our model-driven approach by specifying model transformations based on the AEC-specific cooperation model. In this approach an external service provider could integrate his own services to another project platform (i.e. distributed computing) by describing the data model of his business services.

6.2 About innovative services sustainability and transfer

As the result of the incremental evolutionary development and experimentations of the demonstrator presented in this article, there has been an agreement of professional early adopters from the construction sector on the usefulness of the tool and more importantly on the added value of business services it offers. Thus, *service value and service design* processes (see section 2.1) being accomplished, our role is to make this innovation sustainable by applying the other processes of the S2IP. This part presents the progress and first results of these processes.

The challenge is thus to build a networked value constellations of actors that jointly satisfy a consumer need, where each actor contributes their own expertise and services (Tapscott et al., 2000). The consumer's needs and requirements are here represented by professionals (both individuals and companies) from the AEC sector. The actors are the CRTI-B, software houses interested in selling and supporting the software services and the CRPHT. Regarding the latter, in its RTO role, its objective is not to commercialize the developed software product but more to find partners for doing this and motivate them through the identified value proposition.

Hereafter we describe how the networked value constellation of actors is being put in place through the implementation of the remaining three processes (numbered 3-5 in Section 2.1) of the S2IP.

3) *Service promotion process*: One of the mechanisms that can be used for the promotion of new services within a sector is the standardization approach. In other words, if the sector promotes an innovation as being the standard to be followed, it also strongly boosts this innovation. In our case, the CRTI-B plays this role of standardization body at national level. This was first through the endorsement of the proposed meta-data information structure for the documents. Then, from the experiments we conducted with the demonstrator, the CRTI-B recognizes the importance to

promote its usage in future construction projects. More importantly, the Ministry of Public Construction (one of the partners of the CRTI-B) decided to impose the use of such software services in its future public building construction projects. The CRTI-B will also impose that only a services system respecting the set of requirements formally expressed in the requirements document produced according to the process described above will be eligible.

4) *Service management process*: As indicated above, the role of CRPHT is not to deploy and manage the new designed services by itself. However, its role is to support partners in a successful use and/or commercialization of the innovation. In our case there are 5 consultancy software houses which are interested to develop a software system offering the business services defined according to the requirements document produced by CRPHT today. What they are also interested in is to demonstrate that their developed software is compliant with requirements endorsed by CRTI-B (see above). This is also what the CRTI-B expects from the proposed software. To this end it has mandated the CRPHT in its quality of neutral actor, to check for the compliance of the different proposed solutions with the requirements. So only the companies, which will have produced a 'certified' product, will get the "CRTI-weB" label to commercialize the business services. To do this certification approach, the CRPHT is applying a service/software procurement approach based on a systematic test of both functional and non functional requirements in order to detect and track inconsistencies. Besides an official "CRTI-weB" distribution in Luxembourg area, an open-source distribution of the software solution is also planned. Our aim is to create a community of users and perhaps of providers. The interest is clearly to stimulate a community in order to improve the business services and extend them through 1) business collaborations with service provider(s) and 2) research collaborations with our institutional and research centres' partnership.

5) *Service capitalization process*: CRTI-B has also asked to CRPHT for a follow-up of construction projects managed with the new document management services system. To this end a working group will be set up in order to get feedbacks coming both from the professional construction actors as well as from software houses. The objective is here to enter a Plan-Do-Check-Act (PDCA) model aiming at improving the set of delivered business services through an agreement and the publication of new releases of the requirements document.

6.3 About business service modelling toward project-specific offer

We underlined the importance to adapt the service offer to the specificities of each project situation as a major result of our experiment stage (see section 5). There is a close relationship between project specificities (in terms of actors organization, administrative stages, constructive solution and so on) and the business services to be used. This question has been addressed in other fields, as the "IT-business alignment" issue. We envisage addressing this alignment through two complementary approaches: 1) the meta-modelling and modelling of business service and 2) the collaborative design/composition of services.

The first one aims to integrate five dimensions of business service modelling: the *functional resources* description (e.g. what the service does in business terms?), the *related business processes* derived from the domain modelling, the *non-functional aspects* (e.g. Quality of Service, related Service Level Agreements), the *transactional aspect* (how services are configured together) and the description of *visualization modes* available. Modelling these five aspects of business services is the most generic way to describe them and to enable their flexible composition. In this approach we also target the integration of heterogeneous services e.g. the ones that organizations should develop internally for themselves, and which could be distributed in project teams afterwards.

The second approach addresses collaborative service design for specific projects situations through the integration of multiple expert viewpoints: the *business requirements viewpoint* (i.e. what are the project practices?), the *business solution viewpoint* (i.e. how services can support these practices?) and the *technical solution viewpoint* (i.e. is the service compatible with a particular infrastructure?). Collaborative service design approach is characterized by numerous experts, bringing their own viewpoint. Business service modelling has to separate these viewpoints in order to enable the reuse of the services from one situation to another. In other terms, a service described in a business-oriented language could interest domain specialists for specific AEC project situation. Then technical experts have to control that such a service is adapted to the technical infrastructure used. The reverse is also important: it could allow IT-experts to analyze business services capabilities in order to suggest them at business requirements level (e.g. when business experts are defining the work practices).

Modelling the IT-services will be implemented in relationship with our Cooperation Context modelling infrastructure. It will allow us to apply concepts mapping between domain-specific models and business service models in order to describe functional and non-functional aspects based on a domain-particular semantic. Moreover it lets us envisage linking the service composition description to specific domain processes instantiated from our meta-model. The Dest2Co research project (2009-2010) implements these two approaches and aims at producing a collaborative service design methodology. The expected results could improve business service design fitting specific AEC project cases (e.g. set of working practices to be realized in the project).

7. CONCLUSION

This article applies a Sustainable Service Design Process (S2IP) to define business services for supporting cooperative activities in the construction sector in Luxembourg. In particular, it focuses on innovative services value identification and on business services design processes for improving document management practices in AEC projects. The innovation of the approach relies especially on a high implication of the AEC sector professionals through the CRTI-B national standardization body.

"Service Value" and "Service Design" activities are addressed by distinguishing human and IT issues. Multiple stages involving practitioners allowed us 1) to identify best work practices (first survey/interviews), 2) to let practitioners mutually agree on them (working group), and to suggest business services supporting and improving them (incremental development and validations). The appropriation by the end-users has been tackled through their high involvement in the design and the experiment stages (the latter still under progress).

The development of innovative document management business services themselves has been implemented according to the Model-Driven Engineering, a paradigm enabling the modelling of the business domain, guaranteeing the alignment of services to the business semantic and the rapid prototyping of the services. This development is carried out in the framework of a Sustainable Service Innovation Process (S2IP) driving the various R&D projects of CRP Henri Tudor.

Besides a continuous improvement and formalization of the S2IP through the capitalization of other innovations performed in the context of open networks of stakeholders, more technical work is pursued in two directions.

- First, we are opening the document management services to other information systems, especially the ones used internally by some of our partners (e.g. architectural and engineering firms). The interoperability between global document management solutions and these particular services is an essential key to guarantee a high usage of the application in Luxembourg construction projects.
- Second, we are also addressing several prospective research issues related to the development of these services. In particular we plan to improve the description of business services (i.e. their modelling) and of the business domain use cases (cooperation context models, M1). Our aim is to setup a repository of M1 business models, enabling the selection/discovery of business services closely related to the specificities of these business contexts. In the construction domain it will allow us to provide business services offers fitting the particular context of each architectural project.

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