Designing IT services for the Construction Industry. Lessons learnt for Selection of Validation Techniques

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ABSTRACT: Setting up collaborative working practices is a major stake in construction projects because each project is specific in terms of actors involved, documents produced and building elements designed. In such contexts the use of IT groupware tools to improve collaboration and their efficient appropriation by AEC practitioners is really a challenge. Designing such innovative collaboration-support services is an issue largely addressed in the scientific community especially to identify the factors of success/failure of the tools, but also to identify the scientific experimental approaches underlying it. This article describes five case studies of cooperation-support IT developments and for each of them the validation techniques used. It suggests an analytic framework distinguishing between 1) research project aims, 2) working practices and 3) IT developments types. Finally it introduces three experimental levels to be achieved in various research projects types and describes their related experimental properties.

1 INTRODUCTION

In the construction industry numerous information systems are currently available. While Computer Aided Design (CAD) tools are today well used by practitioners, groupware systems are far from widespread. One of the reasons is that the teams of actors involved in construction projects are heterogeneous and short-lived (i.e. constituted for the project duration). Therefore, setting up collaborative working practices based on a particular groupware system is really a challenge. The design of IT services supporting collaboration in the construction industry is a major area of research and has to 1) face the requirements of Architecture, Engineering and Construction (AEC) practitioners and 2) fit their particular working practices.

In this paper, we address the issue of validation in the process of designing IT services supporting collaboration. We distinguish between two types of research initiatives. On the one hand, *prospective research* works aim to demonstrate the added value of hypothetical working practices with innovative IT services. In this case, either working practices are well known or are suggested by the researchers as hypotheses. Based on these practices, they suggest prospective support services and/or visualization modes.

On the other hand, *applied research works* aim at designing tools able to be rapidly transferred to the sector. They focus on improving existing or emergent practices thanks to IT services. While working practices are the basis of the research, we consider that they have to be re-envisaged through the specific viewpoint of collaboration. Therefore redefining working practices in a “mutually agreed” way with practitioners is a key to the success of service design.

Beyond the design (and the implementation) of IT services, the article suggests to investigate the validation techniques enabling the researchers to validate it. For some years, our research group has carried out projects in the field of collaboration support tools in the AEC sector. MAP-CRAI is a research laboratory working on prospective services and visualization for the AEC sector. CRPHT together with CRTI-B (a construction-representative professional organism) carries out applied research projects to improve electronic cooperation in the AEC sector in Luxembourg.

Prospective works and applied developments have led us to develop prototype tools and to set up specific validation methodologies. We suggest analyzing 5 different projects and describing for each of them 1) the crucial aspects to be validated, 2) the way that we performed it and 3) the lessons learnt from each validation process.

After a brief state-of-the-art (part 2), we describe case studies in both prospective and applied research and consolidate the results of our analyses (part 3). In part 4, we formulate the lessons learnt from this experience through identifying three levels of experiments and their associated properties.

2 EVALUATION OF COOPERATION-SUPPORT SYSTEMS

Research in construction has to face difficulties for evaluating IT innovative applications under design.

A lot of techniques exist for evaluating IT services. The work of J. L. Andresen (Andresen 2002) identifies 82 methods (financial, quantitative and qualitative methods) and the list is not exhaustive. This list identifies the techniques that the companies from the construction industry use for evaluating their IT investments (e.g. Return On Investment, Value Analysis, User Information Satisfaction…). Our approach is slightly different because the objective is to evaluate applications during their design stage. In our case, evaluation concerns a prototype and allows validating the expressed hypotheses.

In hard sciences, the process of hypotheses evaluation corresponds to an experiment carried out in controlled environments (i.e. in laboratories). In our field of research, experiments have to reflect the whole complexity of construction activity (i.e. situated production, non serial production, ephemeral teams…). Carrying out experiments in such a context is therefore particularly difficult (Halin et al. 2004). In addition, mobilizing professionals (i.e. potential users of the IT service) during a long period of time is not realistic for a non-functional product.

Moreover our field of research more specifically targets cooperation-support in AEC projects where collective working practices are not well defined and differ from one project to another. Therefore designing innovative IT cooperation-support services faces the difficulty to fit the specific working practices varying from one construction project to another. Beyond service design, the validation process itself is confronted with this complex cooperative context (Herskovic et al. 2007) and assessment techniques have to take this into account to be scientifically valid.

It appears also important to distinguish between applied research and prospective research projects because the finality of these two research types is different. In applied research, the finality is the transfer of an application towards the professionals whereas in prospective research, the finality is to validate a theoretical hypothesis.

Requirements engineering has to take into account the type of research projects and the method to define services specification varies. Prospective research requirements are based on top/down approach, driven by technology prospects and relying on either existing or hypothetical business practices. Requirements engineering in applied research projects is based on a bottom/up approach, taking existing practices as input or collaboratively defining them together with practitioners (i.e. the future users). Consequently we consider that the experiment device (i.e. “validation techniques”) cannot be the same.

3 CASE STUDIES IN THE FIELDS OF PROSPECTIVE AND APPLIED RESEARCH

We suggest addressing the issue of validation technique selection through the description of some of our previous research projects. For two of them we describe below the precise context, objectives of the development and validation techniques used. For three others we briefly present the validation methodology and the main results obtained. Finally we try to consolidate these approaches based on our validation techniques canvas presented above.

3.1 *Bat’iTrust, an experience in the field of prospective research*

The Bat’iTrust prototype has been developed in the framework of a thesis work about the opportunity to use trust indicators to manage the building construction activity (Guerriero et al. 2008).

3.1.1 *Bat’iTrust, a trust-based construction management prototype*

The thesis work has led to the identification of trust criteria in construction activity and the definition of a trust calculation method. The aim is to extract trust indicators from available knowledge related to the cooperation context dispersed in different tools and views. Then this method has been implemented in a prototype, which is called Bat’iTrust.

This prototype is based on a multi-views interface composed of a trust-based dashboard (displaying construction tasks and their associated trust indicators values) and diverse configuration of views specifically selected to understand the values of trust. The interface of the dashboard represents a list of construction. Each task is associated to its state (i.e. on hold, in progress…), and five different types of trust indicators:

– *Task progress-Specific* Trust Indicator (concerns the progression of the task under consideration),
– *Actor-Specific* Trust Indicator (concerns actors in charge of the execution of the task under consideration),
– *Document-Specific* Trust Indicator (concerns documents required for the execution of the task),
– *Building element-Specific* Trust Indicator (concerns building elements resulting from the task).
– *Global* Trust Indicator (makes a weighted average of the four values of specific trust).

Bat’iTrust puts into relationship a Specific-Trust Indicator in the dashboard with a specific configuration of views corresponding to the four dimensions of the activity (i.e. task progress, actor, building element, and document). Each of these configurations is composed of AEC-specific views well adapted to understand a dysfunction occurring on a specific dimension.

This device allows the coordinator to rapidly identify the tasks characterized by a weak level of trust. A potential risk of dysfunction exists for these tasks. The navigation in Bat'iTrust allows the identification of weak trust level and helps to understand the situation. Concretely, when the construction manager identifies a weak trust level, he can select the Specific-Trust Indicator, and Bat'iTrust generates a configuration of views adapted to more easily understand the nature of the dysfunction.

Let us consider for example a task associated to a weak Task progress-Specific Trust Indicator. In this case the construction manager could select this indicator and access information specific to the task-progress configuration of views. This one is composed of:

- A view "Planning" illustrating the construction process.
- A view "Remarks in the meeting report" displaying the open remarks which have been identified during the building site meeting.
- A view "Weather forecast" stating the weather forecast on the building site.

To improve the readability of information, Bat'iTrust highlights in these views data corresponding to the construction task under consideration (e.g. the line corresponding to the task in the Gantt planning).

3.1.2 *Bat'iTrust business services*

Bat'iTrust software service is aimed at supporting the perception of the cooperation context, and more specifically the visualization of the level of trust in the construction project. Therefore, Bat'iTrust provides only a limited number of business services in order to facilitate the consultation of project information through specific points of view. Bat'iTrust offers only visualization of project data, and no editing functionalities.

Selecting a project leads to its dashboard. The elementary prototype proposes a search module within the dashboard. The more construction tasks and the bigger the project size, the more useful this functionality is to rapidly find a given construction task within the dashboard tasks list.

Four points of view are available in Bat'iTrust: status of tasks, actors, building elements and documents. While consulting them it is easy to move contents, to reduce or enlarge windows, or to go back to the initial settings.

3.1.3 *Validation techniques*

Bat'iTrust is a research proposition based on prospective working practices hypotheses. Therefore it is characterized by two validation stages. The first one has allowed justifying the trust criterion required to calculate the values of trust indicators (i.e. Task progress-Specific Trust Indicator, Actor-Specific Trust Indicator, Document-Specific Trust Indicator, Global Trust Indicator). It has relied on a survey questionnaire for identifying sources of trust in construction activity. The questionnaire has been submitted to 14 professionals of the construction sector (architects, engineers, construction managers, contractors). Then the data have been consolidated in graphs and analyzed. They have been discussed and the final list of trust criteria has been constituted.

A second validation stage has been carried out for the validation of the Bat'iTrust prototype itself. An experiment has allowed validating the hypothesis of trust as support for the construction management. This experiment was based on a simulated context inspired about a real construction project. Seven people (architects (3), students (2) and architect-researchers (2)) have taken part in this validation stage. The process was structured in three steps:

- The experimental subject consults paper documents (e.g. planning of the project, meeting reports…) usually used for supporting construction management.
- The experimental subject uses the Bat'iTrust prototype. During this stage, software is used to capture his actions on the screen and his expressions thanks to a webcam.
- Finally a questionnaire is submitted to the experimental subject. The questionnaire is intended to obtain feedback about the utility and the usability of the proposition.

After that, the data have been analyzed. Recordings have been studied to extract qualitative information about the proposition. The questionnaires have been analyzed. Data have been consolidated into graphs and have allowed drawing a first conclusion about trust as support for construction management. Trust appears really interesting for experimental subjects to assist construction management.

3.1.4 *Experiment results*

These two validation stages have allowed us to:

- Consolidate a list of criterion of trust in coherence with the specific needs of the construction sector. This list has been essential to guarantee that the trust indicators take into account good information sources.
- Validate the potential of trust indicators for supporting construction management.

These two stages have allowed answering the pre-defined objectives, which were linked to the validation of a theoretical hypothesis. This type of validation has some limits:

- The conclusion is based on a weak number of experimental subjects feedback,

– The experiment is based on a non-functional prototype,
– The prototype supports a simulated context of construction project.

Consequently, it is important to consider that the conclusions have to be consolidated with new experiments in a real context.

This experiment has also allowed identifying potential improvements of the prototype about the visualization of the indicators. At this time, some of them have already been considered as new functionalities of the Bat'iTrust V2.0 prototype.

3.2 *CRTI-weB [Document Management], an experience in the field of applied research*

CRTI-weB [Documents Management] is a service dedicated to the exchange of documents in AEC projects. It aims at supporting cooperation processes within those projects - identified as emergent best practices from the field - with CSCW (Computer supported collaborative work) services.

On the statement that IT tools are often single business oriented, present a lack of interoperability and offer only partial representations of the cooperation contexts to their users (Kubicki et al. 2007), our objective focuses on the design and appropriation of new software services to support cooperative activities, taking into account the well-discussed specificities of AEC projects (Kubicki et al. 2006a).

3.2.1 *Approach for the design of CRTI-weB [documents management] tool*

The design of CRTI-weB documents services – focusing on the alignment between AEC projects needs and the appropriation by end-users – involved these end-users all along the project. The first activities consisted in identifying the shortcomings of existing software solutions, the potential best "working practices", their translation in functionalities and the monitoring of end-users appropriation.

During the first activity, enquiries were performed and showed that most of the users were not really satisfied with the existing software solutions they previously used. Some reasons were collected through brainstorming with practitioners. Interesting synthesis papers also introduced some metrics and indicators to understand the factors of success or failure of AEC groupware solutions (Nitithamyong et al. 2004; Nitithamyong et al. 2007).

Then, as the decision was taken regarding the development of a new solution, initial needs have been formulated by the end-users themselves through an enquiry/interview stage. Working practices and cooperative behaviours have been collected by CRPHT who transformed them into a comprehensible set of "best cooperative practices". Dedicated working groups then allowed the practitioners to debate and finally agree on standardized best practices in a consensus way.

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

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

This service-based innovation process is further described in (Kubicki et al. 2009).

3.2.2 *Objectives of the validation*

A review of literature on the topic of technology appropriation factors applied to IT innovation in construction highlighted the usefulness of systems functionalities and their alignment with business needs as factors of success or failure on the adoption of IT technologies in construction projects (Nitithamyong 2004). But the authors also notice that organizational (Alshawi 2007) and psychological factors (Tatari et al. 2004) had to be considered, as well as the user's perception (Davis 1989).

In a perspectivist approach, we consider that appropriation of the new service was 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, 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 the individual has of it, the tool becomes an object of knowledge as the users gets to know it better.

The process of appropriation can be considered through three dimensions (Dumont et al. 2008):

– On the one hand, the technical appropriation refers to a co-adaptation, in which the users adapt the tool to their familiar uses and adapt themselves to the characteristics of the new tool and to the norms embedded in it.
– On the other hand, the social dimension of appropriation focuses on the users as individuals, social actors whose behaviour is regulated by social norms. The tool is 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 it comes in and by the individual objectives of the actors.

– 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 to the others, favouring motivation and trust.

3.2.3 *Validation techniques*

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

Drawing on the above-described dimensions of appropriation we structured our approach in four dimensions (Dumont 2008):

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

Our reflection on appropriation of the tool by its end-users focused on the four above-described dimensions. 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 criterion, i.e. how would the criteria be assessed, i.e. a mean to quantify or qualify the criterion. The parameters would be the data composing the formula of the indicator. This was achieved though a "post-it brainstorming session" where all participants wrote down their ideas on Post-it©-Notes, put their suggestions in common and discussed them. 12 criteria of appropriation emerged from this session. From these discussions emerged a common understanding of the appropriation of the 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: that is 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. For the project team members get more deeply involved in the strategic management process as 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 towards the accompaniment actions to foster the appropriation of users.

The scorecard is used to manage the appropriation of the services during the testing period.

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. 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 helped us 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, starting September 2008 and still in progress, consisted in 4 "pedagogical" experiments and 5 professional experiments, further detailed in (Kubicki 2009).

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 it manages.

– *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 in the new service. As a result, since September the number of new bugs decreased and the correction delay was respected (it never took more than 3 days to be solved).
– *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. pedagogical projects). On the one hand, we notice that globally the practitioners 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 the fact of all the users.

Only a few early adopters use these innovative services and seem satisfied of it. We plan to collect more qualitative data at the end of the experiment stage. On the other hand, we assess that educational projects do not widely make use of the document management business services designed. The software tool 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.

- *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 wider. 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.
- *Cooperation practices*: The experimental stage also aims to disseminate best cooperative practices in the building construction sector. Then the appropriation scorecard also monitors how the use of the software service helps to diffuse the best practices in the construction 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 it after a test period. This dimension will be assessed in final enquiries.

Experiments are still in progress, and final enquiries will give us more qualitative information about perceived usefulness and usability of the software service. The appropriation Scorecard helped us:

- Validate the usefulness of the business services designed,
- Highlight that in each project the use of "advanced business services" is regularly increasing. Only a few early adopters begin to use it and boost these services by promoting it to the others. However there is a lack of qualitative feedback to really validate it,
- Underline how crucial 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 of success.
- Identify some technical limits in the service value design stage such as the multiplication of project platforms or the important time lost in waiting for upload/download transfers…

3.2.4 *Experiment results*

CRTI-weB [Document Management] aims at improving coordination practices among actors in AEC projects with CSCW services. Therefore validation focused on the appropriation process of this service by its end-users. As we consider appropriation as a multidimensional ongoing process, CRTI-weB [Documents Management] has been co-designed and co-validated with AEC actors in a research-action mode of intervention, where validation is integrated at each step, not only managing the appropriation of the services but also contributing to it.

Involving AEC actors all along the design of the service is identified as a key success factor for applied research projects in the field of AEC, focusing on emergent working practices. Involving these actors in the construction of the Appropriation Scorecard, i.e. in the construction of indicators, would have fostered this appropriation but was not possible due to the difficulty of physically gathering AEC professionals.

3.3 *Other projects*

This section is intended to succinctly present three other research projects, and the approach adopted for the validation of each of them. Two projects address prospective research and the last one addresses applied research.

3.3.1 *Prospective research projects*

Image.Chantier was developed in 2003 in the framework of a master research project about the efficiency of photographic pictures to support the coordination of building construction activities (Kubicki et al. 2004). The research works led to a basic functional prototype. The objective of the application was to associate pictures with the traditional content of meeting report. This prototype was tested during several months in a real context of construction activity. However during this period of time the functionalities of the prototype were only tested by one student. Some interviews were organized with some stakeholders of the project to obtain feedback from professionals. This type of validation allows obtaining interesting results but it is limited because there exists no real interaction between practitioners and the prototype to be validated.

Bat'iViews is a prototype carried out in the framework of PhD research (2003-2006) about multi-visualization to support coordination of the building construction activity (Kubicki 2007). This prototype suggests several arrangements composed of the following views: planning, meeting report, 3D model, list of remarks of the meeting report. The prototype suggests a free navigation within the views and the selection of an element in one of these views allows highlighting the corresponding information in the other views (e.g. selecting a task in the planning allows highlighting the corresponding building element in the 3D model). The prototype has not been confronted to professionals until now. The validation stage relied on the definition of diverse scenarios (use cases) close to real coordination situations on building sites. The use cases have allowed validating the utility of the prototype in some coordination situations. It is sometimes really difficult to find some professionals to test prototypes. Therefore, this type of validation can consist in a first step of validation. The results in this case are limited but allow the researcher to stabilize his proposition before a real experiment demonstrating the prototype to some professionals.

3.3.2 *Applied research project*

CRTI-weB [Meeting reports management] is a prototype developed in the framework of the research project Build-it in Luxembourg (2004-2006). This prototype is intended to support the traceability of information around the construction activity meeting report (Kubicki et al. 2006b). It supports the editing and the consultation of meeting reports. Moreover it supports the interaction between stakeholders about the content of the document. This prototype results from the identification of emergent best practices related to the meeting reports management. These best practices were identified in collaboration with professionals during interviews and workshops in the same consensual way than in the case of the CRTI-weB [Document management] best practices (see part 3.2). The validation of this functional prototype has been carried out through 12 pilot project experiments from early 2006 until 2008. Its objective was to validate utility and usability of the designed services, to identify potential improvement on the related practices as well as to federate a socio-technical network of early adopters.

The results demonstrated the interest of supporting meeting reports management through an information system. After the closing of experiments, the tool remained available and the users continued to use it today. Based on these good results the transfer of this tool to the sector is currently in progress together with CRTI-weB [Document Management] tool.

3.4 *Consolidated results*

The five above-described projects come in two categories, from prospective to applied research projects.

On the one hand, ImageChantier, Bat'iViews and Bat'iTrust are aimed at testing hypothetical working practices from the research; we hereafter call them prospective research projects. Two validation scenarios were implemented to validate these projects: use cases and controlled scenarios.

– Use cases are descriptions of a system's behaviour as it responds to a request that originates from the user scenarios. They were used in Image.Chantier and Bat'iViews to describe the hypothetical working practices. Validating these use cases was achieved by implementing then in a "demonstrator": a software application that only proposes successive screens and does not offer

Experiment properties		Prospective research			Applied Research	
		ImageChantier	Bat'iViews	Bat'iTrust	CRTI-weB Meeting report	CRTI-weB Documents exchange
Experimental scenario	Use Case	-	X	-	-	-
	Controlled scenario	-	-	X	X	X
	Real project	X	-	-	X	X
Tool	Demonstrator	-	X	X	-	-
	Elementary prototype	X	X	X	-	-
	Functional prototype	-	-	-	X	X
Collected data	Utility	X	X	X	X	X
	Utilisability	-	-	X	X	X
	Socio-technical network	-	-	-	X	X
	Impact on practices	-	-	X	X	X
Device	Survey	-	-	X	X	X
	Interview	X	-	X	X	X
	Observation	X	-	X	X	X
	Appropriation ScoreCard	-	-	-	-	X
Public	Researcher	X	X	X	X	X
	Professional	-	-	X	X	X
	Student	-	-	X	-	X
Data treatment	Qualitative analysis	X	X	X	X	X
	Quantitative analysis	-	-	X	X	X
	Comparison between two situtations	X	X	X	X	X

Figure 1. Validation processes used in the case studies IT developments

any interaction with users. These use cases were shown to researchers who validated them, afterwards elementary prototypes have been implemented but were not really tested. This type of validation only provides information on the utility of hypothetical working practices.
- Controlled scenario is a more interactive validation technique we used in the framework of Bat'iTrust. It consists in a scenario limited to some practices that users can test through an elementary prototype. This elementary prototype (implemented on the basis of the Bat'iViews one) was limited to the hypothetical practices to be validated, translating them into functionalities that could be tested with human interaction. Students, professionals and researchers were involved in the validation process. The process consisted in testing the elementary prototype, under observation of the research team, which collected data on the tests. Interviews were also performed after the tests. This validation scenario is more comprehensive and enables the collection of data not only on the utility but also on the usability of the IT tool. The concept of usability here consists in how users effectively use the services and how they perceive them.

On the other hand, CRTI-weB services - meeting report and documents management - are intended to improve practices in the AEC sector. We hereafter call them applied research projects. Their validation scope is much wider than for previous prospective research projects: it requires considering utility, usability but also data related to the socio-technical network and the working practices.

Socio-technical network consists in validating how actors involved interact around the software, which is critical as CRTI-weB is designed to support collaborative practices in AEC projects.

We also consider it crucial to monitor how the use of this software tool impacts practices within those projects, transferring emerging good practices to professionals. These four dimensions altogether represent appropriation: an ongoing process in which the user makes the tool his or her. So we designed a validation process involving all identified types of stakeholders - professionals, researchers and students - all along the project: from the identification of emerging best practices to their translation into functionalities and the testing phase of the services. We also designed a Scorecard including indicators in the four dimensions of appropriation. The collection of data to feed the Scorecard was achieved through surveys, interviews and observation. We consider the elaboration of this Scorecard as a support to appropriation itself.

Drawing lessons from these projects and the validation process we implemented, we can identify critical validation processes according to the type of project: prospective or applied (Figure 1).

4 LESSONS LEARNT FOR VALIDATION TECHNIQUES SELECTION

We consider that identifying whether the research is prospective or applied, and whether it refers to hypothetical or emergent practices, constitutes the first steps towards the selection of validation techniques.

Moreover the several projects that we carried out let us to introduce three "experiment levels" depending on these hypotheses: Level 0, Level 1, and Level 2. In a research project, determining the experimental level to be achieved (and its associated experimental properties, see Figure 2) is closely related to the project aims.

Level 0 is the experiment level required in a short research project (e.g. student research training) where working practices could be either hypothetical or emergent and where the IT tool developed is often basic (demonstrator). The experimental scenario relies on use cases identification (Halin 2004). Collected data informs about the utility of the proposition. Use cases can be established on the basis of terrain observation and they can support confrontation of the proposition to researchers from the community. Experiment duration is short in order to rapidly obtain qualitative data. Validation can be based on the comparison between two situations: the one without the proposition and the other with the proposition.

Level 1 is required when innovative hypotheses address working practices (e.g. in a Ph.D. project) or when the IT tool is robust enough to be exposed (elementary prototype). Controlled scenario is the most adequate experimental scenario identifying a representative cooperative context in which we could identify the utility of the proposition. The state of the development of the elementary prototype enables to present it to researchers, students but also to practitioners (e.g. early adopters). It also permits to support interviews and surveys with practitioners as well as observation. The elementary prototype can place practitioners in situation of use in order to collect information about the utility, the usability and the potential impacts on working practices. In this case data to be treated are principally qualitative.

Level 2 is required in the case of applied research projects aiming at transferring IT tools to the construction sector. In this case working practices could be either well known by the practitioners or they have to be identified in a consensus way in order to be transferred after the research project. Therefore validating practices appears as much important as validating the alignment of the IT services with them. Functional prototypes can be experimented within real cases (pilot projects) representing the whole complexity of cooperative construction projects. Appropriation can therefore be assessed through its four dimensions: utility, usability, socio-technical network and impact on practices. Beyond traditional techniques (observation, surveys and interviews), designing an appropriation scorecard together with practitioners appears important as a support to appropriation itself. Quantitative and qualitative analyses of data allow envisaging the transfer of the tool to the construction sector.

5 CONCLUSION

This article addresses the issue of validation techniques applicable in the design of services supporting cooperation in the construction industry. We capitalize on our previous research works in this field in order to identify validation techniques associated to prospective and applied research projects.

The approach suggested here is based on the analysis of 5 case studies: 3 prospective research projects and 2 applied research projects. In prospective research the aim of validation stage is to assess on

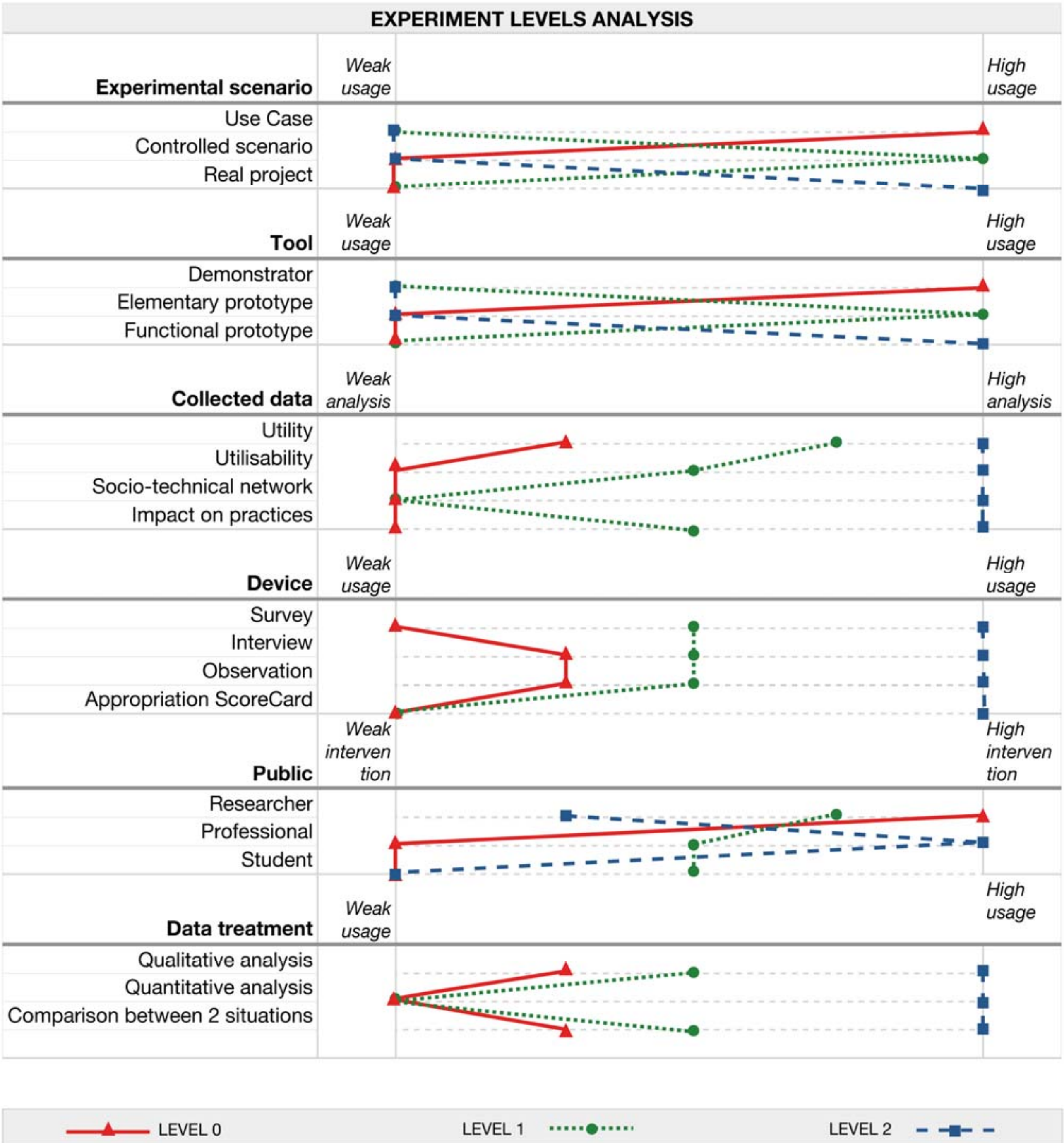

Figure 2. Three experimental levels and their associated properties

the theoretical hypotheses formulated. In applied research projects the aim of validation is to improve working practices and to transfer IT services to the sector.

We introduced three levels of experiment and their associated properties. We conclude that prospective research projects require a *Level 0* or *Level 1* experiment. The main limits impacting such experimental protocols are often related to the state of development of tools and to the difficulty to involve practitioners. Applied research projects (i.e. "action research") require a *Level 2* experiment enabling practitioners to really use the tool in a project. The main difficulty that appears in this case is to identify the adapted pilot projects and to setup networks of volunteer users. We underline the importance to federate a network of early adopters and to provide them with functional/technical support during the experiment period.

Finally, it is important to mention that the three levels of experiment could concern a same research project at different stages of its life cycle. In this case the research project would first begin with innovative hypotheses. And after interesting level 1 and 2 experiment results the aim of the project would become the transfer of an IT tool to the construction sector.

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