A MODEL-BASED APPROACH TO DEVELOP A DASHBOARD TOOL INTEGRATING TRUST CONCEPTS IN AEC

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ABSTRACT: In the Architecture Engineering and Construction (AEC) sector, cooperation between actors is essential for project success. During the building construction activity, the organization of actors is both hierarchical, transversal and adhocratic. Moreover, the quality of cooperation is fundamentally influenced by the management of interdependences between tasks and between actors. In this context, the development of new assistance tools has to integrate these heterogeneous parameters relative to coordination and trust. We inspired about Model-Driven Engineering approach to propose a models infrastructure integrating cooperation context modelling and views modelling. We develop on the basis of this infrastructure a dashboard dedicated to the building site coordinator. This tool currently in design stage provides indicators about the trust in the good progression of activity. Moreover, it would enable context understanding by combining these indicators in a multi-views interface. Thus, the user could navigate in the context using multiple views like meeting report, planning, performance evaluation, or 3D mock-up, and obtain more information about a particular indicator.

KEYWORDS: building construction, cooperation, coordination, trust, process modelling, dashboard, model-driven engineering.

1 INTRODUCTION

The AEC sector comprises actors involved in specific actions and stages all along the building life-cycle (from operation planning, design, construction, use and demolition). During design and construction specific stages, actors' networks involved are ephemeral thus, it is difficult for them to create and maintain durable relations. Professional entities are heterogeneous. It implies that "business logics" are very different notably concerning competencies, operational methods, purposes in the project and constraints linked to the trade itself or to the internal strategies of the companies (Evette et al. 2000).

In this article, we focus on the execution stage and more precisely, on coordination of building construction activities.

A building site is a particular environment. Teams involved each have their own business culture and their own point of view on the building activity. Building construction is impacted by many diverse disturbances (Tahon 1997):

- Dysfunctions related to paper documents. We observe problems in diffusion of documents to concerned persons, the lack of updates, the missing of modifications documentation, or errors linked to the bad understanding of documents.
- Dysfunctions related to interactions between actors. They are linked to unawareness of others or to mistrust between actors who need to collaborate. For example, each building trade uses its own specific vocabulary and sometimes communication can be quite ambiguous.
- Dysfunctions related to tasks. Particularities of building elements and building techniques imply risks in construction tasks.
- We also notice risks due to execution environment (building site) and weather conditions.

In this context, the building construction coordinator has to limit the dysfunctions and/or their impacts. These should be mentioned in terms of building quality lacks, over delays, or cost rises. In the French AEC context, a building construction coordinator manages organization, and coordination of the activity. His mission consists of facilitating documents diffusion, detecting decisions to make, providing essential elements to decision-makers, and indicating risks existing in the activity (Armand et al. 2003). Concretely, the construction coordinator has to define procedures relative to the documents (such as updating or diffusion methods), to the technical management, and to the delay and cost monitoring all along the project. He also leads coordination meetings enabling the monitoring of the project progression and the identification of potential construction problems.

In this article, we will begin with an analysis of the AEC context and we will look at organizations, coordination mechanisms, trust and tools for the construction coordination. Then, we will address modelling of the AEC cooperation context and the views used in coordination tools.

Finally, we will propose a Dashboard for the coordinator to identify trust in the execution activity.

2 STUDY OF THE AEC CONTEXT, A THEORETICAL BACKGROUND

2.1 *Organizations and coordination*

XX^{th} century theories on organizations focus essentially on their formal structure. Studies by Henry Mintzberg appear especially interesting when it comes to distinguishing between organization forms (Mintzberg 1979). We retain here three major forms useful in our area of research: “hierarchical” organizations, “transversal” organizations and “adhocratic” organizations.

- “Hierarchical organization” covers traditional enterprise forms identified in theories of scientific management (Taylor 1911). It is characterized by a bureaucratic organization (Weber 1921) and managed by organization charts.
- When organization becomes more complex and dynamic, there is more standardization of methods and processes. In some cases these organizations cover numerous project contexts. We then talk about “transversal organizations”.
- The adhocracy concept introduced by Toffler covers a more “democratic” vision of collective work (Toffler 1970). In “adhocratic organizations”, decisions should be distributed between actors and personal strategies should be preserved.

The characteristics of coordination are related to these three main forms of organizations. Mintzberg distinguishes essentially between three coordination mechanisms (Mintzberg 1979):

- In “direct supervision” one person is responsible for the work of others. This person has to plan the process and to communicate it explicitly to the actors,
- “Standardization” appears when coordination of the different workers is incorporated in the program in early design stage, or in reference documents. The need for communication is then reduced,
- “Mutual adjustment” ensures work coordination by way of informal communication between concerned actors.

Moreover, we can make a link between these coordination modes and specific organizations (See Table 1). In the following parts of this paper we will focus on building construction activities.

Table 1. Organizations and Coordination in AEC projects.

Configuration of the organization	Coordination mechanism
Hierarchical	Direct Supervision
Transversal	Standardization
Adhocratic	Mutual Adjustment

2.2 *Trust: sources and organizations*

If coordination is essential in the cooperation to manage the dependences between activities, trust is also important to manage dependences between actors. Trust consists in a fundamental element of the cooperation. It is associated with expectations in the behaviour of another party (Rotter 1967) and constitutes, in a context where the future is uncertain, a device allowing to reduce the complexity of the future and to overpass the risk (Luhmann 2000).

A lack of trust between actors leads to a paralysis of exchanges and in such a context, we cannot seriously envisage a fruitful cooperation.

2.2.1 Sources of trust

Our state of the art allowed us to highlight different sources of trust (Zucker 1986, Kramer 1999). We have considered neither individual characteristics, nor psychological aspects and we have distinguished the following sources:

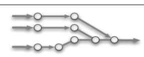
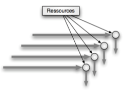
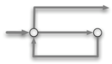
- Trust based on characteristics. This trust is based on internal characteristics of the individual, like culture and the group in which he is involved…
- Trust coming from a third party. This trust corresponds with the notion of reputation. Indeed, reputation is a fundamental element for the construction of trust in a situation where actors do not know the other party and want to create a first collaboration.
- Trust coming from previous experiences. This trust is based on the fact that people have already worked together. It is constructed from exchanges made in the past and is based on the performance of the actor and past successful references.
- Trust coming from the role. This trust corresponds with a trust relative to the performance of an actor according to the role he has in an organization. It is a depersonalized trust because trust comes from the role independently of his competences and capacities to reach fixed objectives.
- Trust based on rules. This type of trust is based on contractual mechanisms, rules, certification organization or norms.

2.2.2 Trust in organizations

Zolin’s works (Zolin et al. 2000) are particularly interesting because they are about trust in AEC sector. These works are based on Thompson’s approach to interactions between actors (Thompson 1967) and characterize three interdependence situations:

- In a “sequential interdependence” situation, input of an actor corresponds to the output of another one. Trust of actor A providing output to actor B necessary for his activity is based on emergency information transmission. Trust of actor B is based on possible transmission by actor A of information relative to incapability for him to achieve specifications or deadlines.
- In a “reciprocal interdependence” situation, actors mutually transmit work. The level of interaction between actors is high. Those actors have to trust each other concerning information exchange relative to the impact of decisions on costs, delays or quality. Moreover, they have to trust each other to find solutions concerning their common activities.
- In a “pooled interdependence” situation, actors share common resources but they are independent. The level of interaction between actors is weak. They trust each other concerning the respect of quality goals, quantity goals and deadlines.

Table 2. Organization, coordination and trust

Configuration of the organization	Coordination mechanism	Type of interdependence	Sources of trust
Hierarchical configuration	Direct supervision	 Sequential interdependence	Trust based on roles
Transversal configuration	Standardization of results Standardization of processes Standardization of qualifications	 Pooled interdependence	Trust based on rules, norms, contracts… Trust based on reputation
Adhocratic configuration	Mutual adjustment	 Reciprocal interdependence	Trust based on previous experiences

In table 2, we complete our approach to organizations and coordination mechanisms (See Section 2.1.) and we integrate trust and interdependence aspects. This table highlights the fact that "Hierarchical configuration" is principally characterized by sequential interdependences and a trust essentially based on roles. "Transversal configuration" is characterized by a weak level of interaction between actors and consequently, trust coming from rules, norms that characterize standardization, and from reputation. "Adhocratic configuration" is characterized by reciprocal interdependences and a trust essentially based on previous experiences. It is constructed on the basis of frequent exchanges between actors.

Coordination activity on building sites concentrates principally in the hierarchical configuration. The coordinator is in charge of coordination for the whole building activity and supervises different practitioners.

2.3 *Tools and methods to assist direct supervision on building sites*

The coordination of the building activity is assisted by some tools and methods intended to support direct supervision. This section identifies present and emergent practices.

2.3.1 Present practices for coordination on building sites

We identify principally two types of device intended for the coordination of the building activity: planning tools and tools for meeting report writing.

To manage coordination, the coordinator uses planning tools intended to create two types of planning: Gantt planning and Pert planning. The Gantt planning determines tasks to perform, the processes and temporal interdependences (e.g. end of a tasks conditions the beginning of another task) and possibly, the percentage currently executed. The Pert planning (Project Evaluation and Review Technique) is composed of tasks and steps. It allows the determination of the optimal configuration for the process and the identification of critical path linking tasks in which a delay would penalize the whole building construction activity.

The building construction meeting report provides information about the state of the construction activity at a given moment. It is written after each meeting and includes in a document, which will be validated by all the participants, all the decisions taken, identified problems (more and more often illustrated with pictures), the state of progress and also diverse information. These documents are generally written with a simple word processor.

2.3.2 Emergent practices for the coordination on building sites

In emergent practices for building activity coordination, we can identify the contribution of 4D CAD tools. They consist of an interface that shows the relation between the 3D mock-up and the execution planning (Sadeghpour et al. 2004, Chau et al. 2005). The objective of such tools is to simulate the state of the building construction activity at a given moment. Moreover, it considerably improves communication with the owner and it allows ripening the execution planning.

We can also identify dashboard tools which are being used increasingly in all sectors including in the construction sector with solutions such as the one proposed by Primavera[1]. The dashboard is a decision support tool, it informs about the state of the activity and offers a synthesis view with relevant indicators.

At last, evaluation systems like RatingSource[2] or AEC Performance[3] are beginning to appear in the construction sector. These tools allow the evaluation of the professionals' performance during a building construction activity. The objectives of such tools are principally to give to owners information related to construction firms' performance during the bidding phase, to control actors' activity with regular evaluations, to identify points to improve for evaluated firms, and to use past evaluation to give references for future clients. These tools are totally integrated in the approach of trust, principally coming from previous experiences and from the reputation. But it is difficult to share these evaluations and some deontological problems could possibly appear, like the limitation of bidding only for firms with best evaluations.

These tools, which we have identified above, have a real utility in construction activity coordination. They inform about the construction process, about the state of the activity and its performance. However, the difficulty for the coordinator is to obtain a global vision of the cooperation context because information is fragmented. We think that it is necessary for the coordinator to have tools that can improve his perception of the activity in order to better adapt his action to the context.

3 MODELLING THE AEC COOPERATION CONTEXT

Up to the present, we have determined the theoretical framework of the AEC context in which our research work is joined. We will focus in this section on the aspect of modelling of the AEC cooperation context.

3.1 *Model driven engineering approach*

Our approach is based on models development, steering both sector analysis and tool engineering. This method is

[1] http://www.primavera.com
[2] http://www.ratingsource.com
[3] http://www.aecperformance.com

largely inspired by existing methods in the software engineering sector.

Since 2000, the Object Management Group has developed an approach called Model Driven Architecture (MDA) for software systems development (Soley et al. 2000). Their objective is to define a framework of certified industrial standards (e.g. MOF and UML).

In parallel, the Model Driven Engineering (MDE) research area is an evolution aiming to unify different technical spaces of computer science (XML, ontology etc.). It does not focus on a single technology: it is an integrative approach (Bézivin 2005).

Concretely, 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). Finally, the transformation concept is a central one. It allows the models to be productive. A transformation is itself described with a model.

3.2 *Modelling the cooperation context in AEC*

We use this methodological framework and propose two levels of modelling for the cooperative activity in the AEC sector. Firstly, we have developed a cooperation context meta-model at a high level of abstraction. This meta-model is used to construct a specific model representing the particular context in an operation of construction. MOF architecture, on which we base this reasoning, integrates perfectly in the approach with models and meta-models of MDE.

Our relational cooperation meta-model takes into account the existing relations between the elements of a project. We identify four main elements existing in every cooperation project: activity, actor, artefact and tool (See figure 1).

A model focusing on the specific building construction activity has been developed (Kubicki et al. 2006). It represents the specific context of construction: construction tasks, actors involved (i.e. firms and facilities), tools used (i.e. planning tools, see part 2.3) or documents (i.e. meeting reports). For example, a building construction model allows us to manage explicitly the relations existing between two documents: a remark in the meeting report concerns a task in the construction planning. This model conforms to the Cooperation Context Meta-Model (Figure 1).

3.3 *Modeling AEC specific views*

The development of new interfaces to be integrated into cooperation assistance tools has to take into account the existence and the specificity of "business-views". These "views" of the cooperation context are those that professionals manipulate in their daily work.

So, we propose modelling the "views" such as they are used in the tools supporting cooperation (which are existing and/or emergent, see part 2.3). We note that these models of "visualized concepts" define only the semantic content of a view, not technical dimensions, navigation model, tasks model and other specific models for HCI.

Then, a view can be represented with three abstraction levels like the levels of modelling of the cooperation context. At the bottom, we find the view itself, i.e. the user interface operated in a tool (e.g. a view of the execution planning). Thus, its model represents the concepts that the interface uses. These concepts are specific for the profession that uses the view. In our example (See figure 2), the view planning represents the "resources" (construction firms), the tasks, their temporal links, and it is a view generally used by the coordinator.

Finally, the meta-model of the view "planning" could be the one of UML.

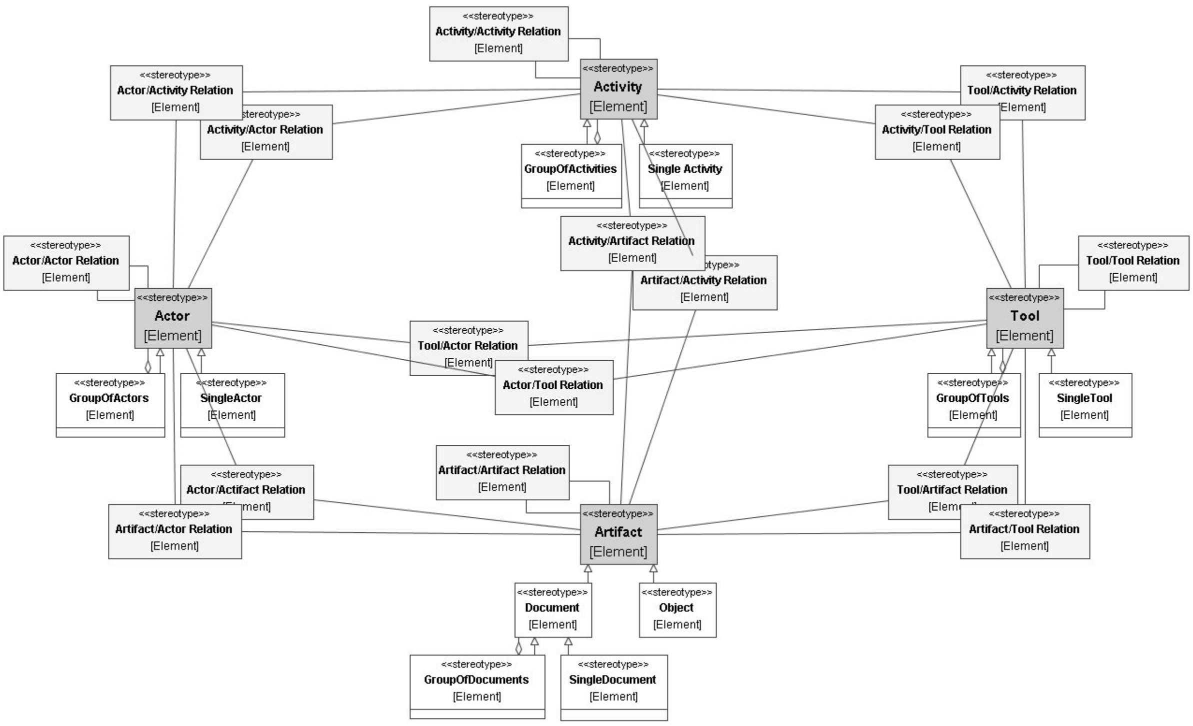


Figure 1. Cooperation Context Meta-model (extract).

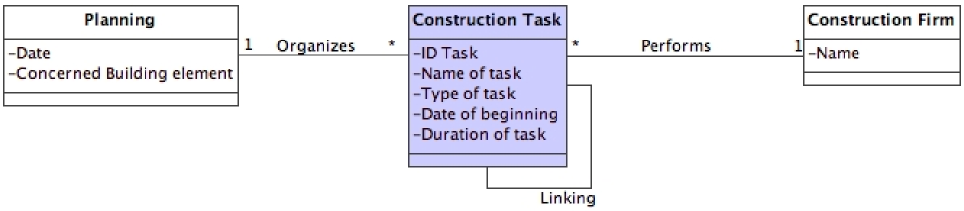


Figure 2. A model of the concepts represented in a view "planning"

3.4 *A models integration infrastructure*

Our method is based on two types of models: model of the cooperation context (See part 3.2) and model of concepts represented in views (See part 3.3). Our needs relative to the use of these models are the following ones:

- To define specific and appropriate tools for the construction sector as they are described in the cooperation context model,
- To establish a methodology to represent views adapted to the AEC domain, notably to design new innovative interfaces,
- Finally, to link views conceptually, i.e. to describe relations between concepts in complementary views. For example, a task in the view "planning" can be associated to one (or more) remark(s) in the view "meeting report". This semantic link can only be expressed according to the specific knowledge of the sector described in the cooperation context.

The integration of these models is translated in an infrastructure that will be used like a methodological guide to develop the interface Bat'iViews and the coordination dashboard (See part 4).

Figure 3 graphically represents this infrastructure. At the centre of the pyramid, we find the levels of modelling of the cooperation context. That is the "knowledge of the construction sector". All around we find the models of views of the context implemented in tools. The views (HCI) are structured on the base of the pyramid according to the same principle: with their model and their meta-model. To construct a particular view, it is necessary to operate a transformation of models to extract the concept from the cooperation context to be represented in the view ("Transformation of models" in the pyramid). At the lowest level, to construct the visualization interface with data coming from the context of a project, the process is established like a transformation and a selection of pertinent information in the context for the construction of view. This operation of selection is performed depending on the model of concepts of the view and it is also relative to other criteria that can be taken into account in the context of the actor using the view (e.g. his role, his right of visibility on information, etc…).

Prospecting the development of cooperation context multi-visualization interfaces, the unification of models proposed by this infrastructure is necessary to homogenize relations between views. So, the cooperation context model gives to the views the global semantics (relations in the cooperation context) in which their concepts are integrated.

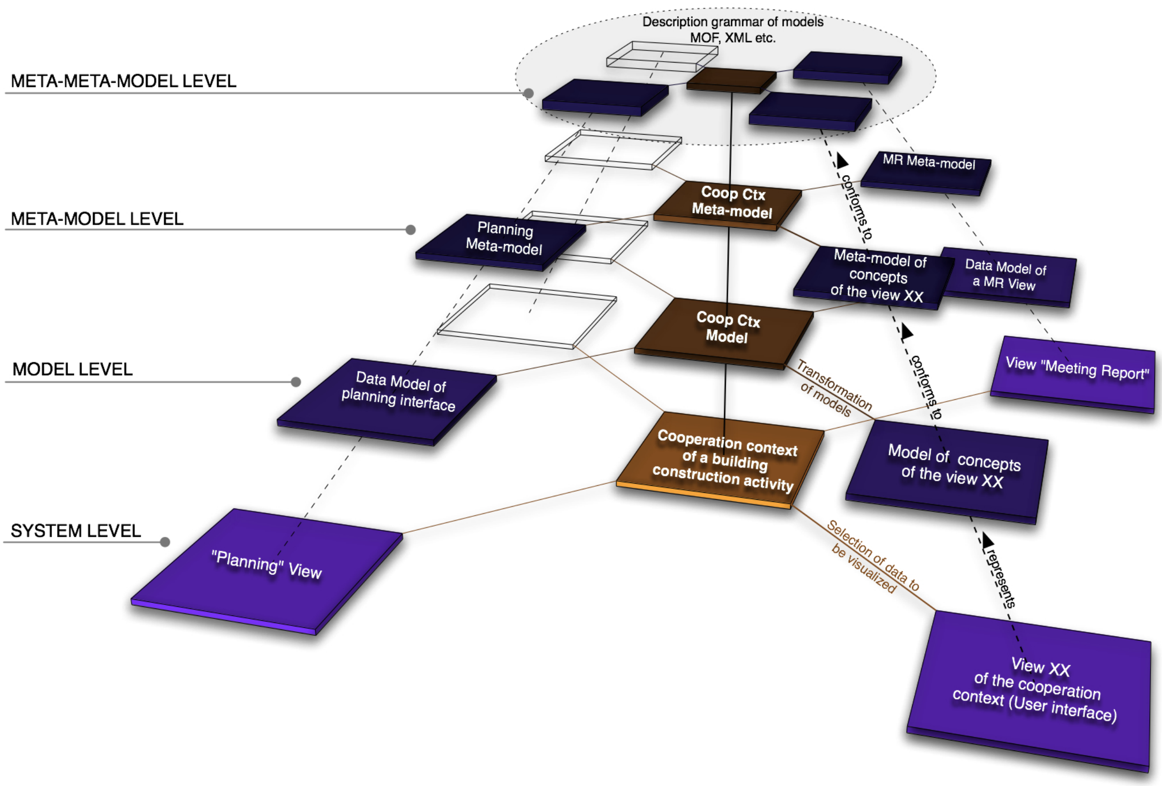


Figure 3. Models integration infrastructure.

4 PROPOSITION OF A TRUST-BASED DASHBOARD FOR THE CONSTRUCTION ACTIVITY COORDINATOR

Our objective in this section is to present an assistance tool for "direct supervision" coordination situations. We are working on a dashboard, currently in design phase, which allows the evaluation of trust in the good progression of the construction activity. This tool is specifically intended for the coordinator and allows the reduction of the impact of dysfunctions on building sites and the definition of a suitable control of high-risk tasks. To fulfil the needs of the construction coordinator and particularities of the AEC sector, we propose a dashboard based on our study of coordination and trust.

Our proposition is in the continuity of a previous research work: Bat'iViews is a multi-views interface intended to bring together views of the context manipulated by the professionals. It determines the infrastructure in which our indicators for the building construction coordination are inserted.

4.1 *Bat'iViews research prototype*

Section 2.3 of this article has shown that information relative to coordination (and useful for the building construction actors) is represented in numerous views attached to documents, coordination tools or communication tools. To improve context comprehension by the actors, it is necessary to provide a representation adapted to the user showing relations existing between the different elements of the context.

Bat'iViews[4] suggests making use of views manipulated everyday by the construction stakeholders and integrating them in a navigation tool showing relations existing between content elements of each one. We choose 4 dynamic coordination views: meeting report view, planning view, 3D mock-up view and a view of all particular points in all meeting reports. In order to show relations between elements of different views, the tool is based on the multi-visualization principle (North et al. 1997, Wang-Baldonado et al. 2000). It provides different views' arrangements to the user allowing him to navigate in the project context. The concepts to link through the views depend on the model of each view: i.e. meeting report displays "remarks" concerning "actors" and "building element(s)", planning shows "tasks" and 3D mock-up represents "building objects". User-interaction is generated by the selection of one of these elements in each view. It consists of finding the corresponding concepts in the other views and highlighting them. Then, we call it a "free navigation": each view can generate interaction and refresh the global interface window.

4.2 *Proposition of a dashboard for coordination*

We suggest representing these trust indicators in a new "dashboard view" integrated in the Bat'iViews interface. This dashboard will coordinate the arrangement of other views, i.e. it will generate the interaction and re-organize the view-arrangement depending on the indicators selected by the user. This means that we will have to introduce new views in the interface such as performance evaluation system, document list, financial monitoring and modifications management.

The new "coordination dashboard" view associates a performance indicator to each construction task. In order to determine the global level of trust we have made the hypothesis that trust in a construction task is high when:

1. Task progression corresponds to planning,
2. Documents linked are updated and exist on the building site,
3. "Single building elements" to construct are not too complex and,
4. Performance of actors involved in the task is high.

These combined elements allow us to obtain the trust level associated to a construction task.

The tool provides a global view of trust levels in diverse activities to the construction activity coordinator. It allows the user to deploy specific tasks when a dysfunction is identified through a low trust level. The detailed view displays trust levels specific for the activity, documents, actors, and building elements concerned by this task. The coordinator identifies then where the dysfunction is and can deploy a specific arrangement to better understand origins and risks of the problem. In the example (See figure 4), the user selects a dysfunction identified in the progression of a construction task. Then, Bat'iViews provides him a three-window interface composed of the planning (highlighting related task), the meeting report (highlighting related remark) and the 3D mock-up (highlighting related building element).

This device intended to the construction coordinator constitutes a four-level dashboard:

- Perception level:
  The dashboard gives a global trust indicator in the good progression of the construction task. The construction coordinator quickly sees tasks in which there are dysfunctions and the detail of the construction task allows him to identify the nature of the dysfunction.
- Understanding level:
  The navigation in the arrangement of views specific to the nature of dysfunction and the relation between views guarantee a global analysis of dysfunction.
- Anticipation level:
  Indicators allow an "a priori analysis" before the task has begun and highlight the impact of an indicator on a subsequent dependent task.
- Assessment and capitalization:
  The integration of a view "Performance evaluation system" in Bat'iViews should allow capitalizing on the experience coming from previous projects and giving an indicator of a priori analysis of the actor's performance.

[4] http://www.crai.archi.fr/bativiews/

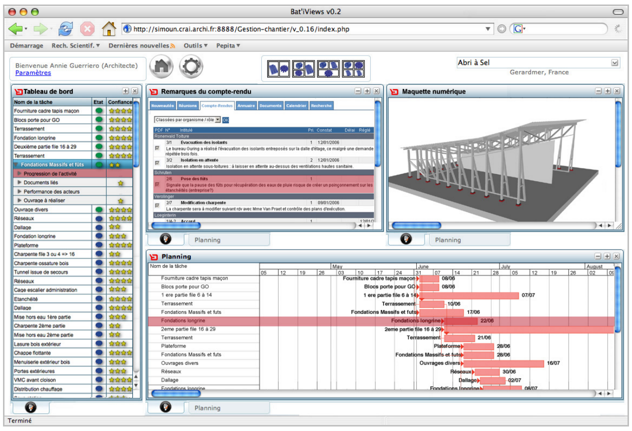


Figure 4. View of the Dashboard based on trust in the activity.

4.3 *Model of the dashboard view*

The development of this view "Coordination Dashboard" is integrated in our model-based approach. It is a "tool" existing in the cooperation context of a building construction activity. At the lower level (Level System), we find the user interface and data operated in the tool Bat'iViews. Then, the Model Level represents concepts used in the interface. The model of the concepts of the view "Coordination Dashboard" (See figure 5) outlines the fundamental element of the dashboard: Trust Indicator in Task State (TITS). It is defined in function of four subtypes of indicators:

- Trust Indicator in the Activity Progression (TIAP) identifies if there are dysfunctions relative to the progression of the activity by using information provided by the 4D model, the planning and meeting reports.
- Trust Indicator in Building Element (TIBE) identifies if there are some dysfunctions relative to building elements and refers to the modifications monitoring list that identifies the differences in comparison with what was expected in specifications.
- Trust Indicator in Documents (TID) identifies if there are some dysfunctions relative to documents workflows and refers to the list of updated documents.
- Trust Indicator in the Actor's Performance (TIAPE) identifies if there are some dysfunctions relative to building elements and refers to performance evaluation reports.

The information sources necessary for the identification of dysfunctions and for the measures of indicators are represented in the cooperation context; these are documents specific to the coordination activity. Finally, for this new view, the meta-model level is associated to the one of UML.

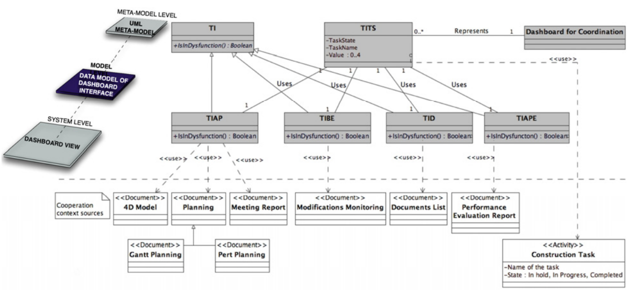


Figure 5. Data Model of the Coordination Dashboard interface

5 PROSPECTS AND CONCLUSION

In the AEC sector, the quality of the progression of projects is directly linked to the management of dependences between tasks and actors. The analysis presented here proposes characterizing the sector through different configurations of the actors' organizations, coordination mechanisms and trust. Our modelling of the cooperation context represents the set of entities identified in the AEC processes. This theoretical analysis leads to a Dashboard intended for the construction coordinator in order to identify the trust in the good progression of the activity. This tool allows the identification of the tasks that contain a risk and the navigation in the context of the project to understand the nature of the problems. It is integrated in the infrastructure based on models and has itself a model of concepts presented here. Moreover, this model describes information necessary for calculation of trust indicators from the cooperation context.

A this stage of our research work, we are envisaging defining precisely the calculation heuristics and developing a prototype of the dashboard to confront this proposition with professionals of the sector in order to evaluate the relevance of the proposition and possibly, to modify it in function of feedback. This development will ensure also a validation of the models integration infrastructure that will constitute the methodological framework of our work.

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