Use of business process modules for construction project management

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ABSTRACT: Projects in the building industry are extremely dynamic and affected by several constraints. Therefore, common principles should be established throughout the construction industry that allow for flexibly specifying and combining construction project information. New members should be supported to easily join and leave the project consortium while still using their own applications. The need to rapidly set up new organisational structures and effectively manage this virtual organisation places high demands on the methods and models that are used to establish the project structure. Consequently, there is a need for an overall model representing the different building objects and functions as well as organisational and IT infrastructure of the projects. The paper presents an approach towards a common meta-model for the representation of construction project information for inter-organisational process management. Furthermore, the applicability of the proposed model for the selection and instantiation of predefined process modules will be demonstrated.

1 INTRODUCTION

Projects in the AEC/FM sector are characterized by a variety of technical and structural boundary conditions. Heterogeneous organisational structures and various IT-systems affect the realisation of a construction project. Particularly, the organisational structure is of great dynamic, since a project passes through several individual phases, such as ‘planning phase’, ‘construction phase’, or ‘operational phase’. Each phase is conducted by its own organisational structure involving large companies as well as SMEs. Moreover, the building structure itself might become extremely complex with the progression of the project. Large construction projects usually comprise thousands of individual building objects and activities.

The use of appropriate IT-systems is of great importance for the management of large projects. However, seamless information processing is rarely accomplished, since each company is using its own IT-applications with incompatible or proprietary interfaces. Thus, a common strategy for the inter-organisational management of construction projects has to be established. A promising approach for integrated project data management has been established by the development of product models (e.g. the Industry Foundation Classes). However, the drawback of these models is, that they are very complex and focused primarily on design instead of management aspects. Again, just partial features are supported by software systems so far. To support inter-organisational construction project management and process coordination, general project constraints have to be described in a general model with regard to domain and project specific aspects.

Besides the benefit for inter-organisational co-operation through a general model, the model can also be employed for process management. Therefore, the oftentimes existing implicit knowledge about the construction processes should be transferred into explicit knowledge and stored in formalised process modules. A first approach for the use of predefined processes for construction projects has been realised in the ICCI[1] project (Katranuschkov et al. 2004). Within this project a great number of construction specific tasks have been defined. However, the handicap of this approach is the concentration on the activity itself as an individual task, while the correlation with the project constraints is limited.

The aim of the paper is to present an approach for supporting inter-organisational construction project management. Therefore, the paper is structured in three sections: 1) presentation of an approach towards a common meta model for the definition of general construction project constraints. This meta model can be applied for the semantic interoperability between the construction project information and the business processes.

[1] Innovation co-ordination, transfer and deployment trough networked Co-operation in the Construction Industry

2) demonstration of the applicability of proposed model for the use of predefined process modules.
3) discussion of a first realisation of the approach.

2 CONSTRUCTION NETWORK DESIGN

For an efficient coordination of the partner activities in construction projects, it is essential to define the objects that influence inter-organisational collaboration. Thus, there is a need for a common meta model for the specification of the project's boundary conditions. Such a *Construction Network Meta-Model* should be qualified to describe and manage project specific information, that are required for an efficient and coordinated project cooperation.

The development of such a meta model will be accomplished in two steps:

- Identification of the context that influences the performance of construction networks.
- Transformation of the identified context into classes, properties and relationships among them.

2.1 Identification of construction network constraint

Construction projects are defined as complex one of a kind projects. Thus, to derive a common meta model for collaborative construction project management its complexity has to be reduced by subdividing them into integral/coherent sub-projects or project views. Therefore, the entire project has to be decomposed into its controlling elements and structured in a reasonable manner.

Based on various sources, interviews and project analyses three key dimensions that control the project's performance have been identified, namely *Project Organisation*, *Project Structure* and *Project Information*. Each of these dimensions can be subdivided again into two or three categories. The dimensions and belonging categories are represented in figure 1.

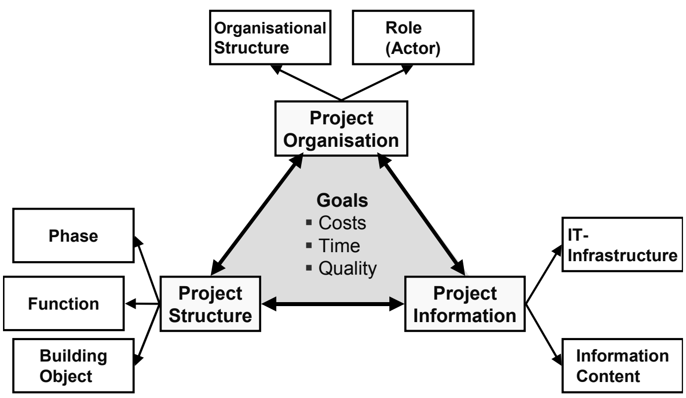

Figure 1: Dimensions and categories to structure construction project constraints

The dimension *Project Organisation* defines on the one hand the organisational structures within a project (e.g. 'general contractor' or 'joint venture'). On the other hand the roles (actors), necessary for the accomplishment of the project, are defined (e.g. 'project manager' or 'planner'). The decomposition of the project into different aspects is realised by means of the dimension *Project Structure*. The category phase divides the project into distinct, closed periods (e.g. 'planning phase' or 'construction phase'). The tasks necessary for the completion of a project are defined by the category function, whereas the category building object structures the project into spatial and/or physical sections. The dimension *Project Information* will define the IT-infrastructure and systems for inter-enterprise information exchange in a project, and will specify the information content that is exchanged between the partners. A more detailed description of the categories and their relations for the *Construction Network Meta-Model* is explained in Keller et al. 2004/2005.

Subsequent to the identification of the context, which influences the project development and the management of construction activities, common information for the dimensions and categories has been specified and classified. Description models for the representation of the categories have been developed based on several construction projects' analysis. In addition, common building data standards and technical regulations were evaluated for its applicability to describe construction project constraints.

2.2 Design of a Construction Network Meta-Model

The partial models of the categories identified in figure 1 have to be integrated into an overall model, the *Construction Network Meta-Model,* leading to a comprehensive specification of the constraints of construction projects. By means of this model the required information for collaborative project management is instantiated for a particular project and semantic interoperability between the categories is realized.

The general structure of the proposed meta-model is depicted in figure 2. In this model an interrelationship between the categories of chapter 2.1 has been established according to the requirements that have been identified in the projects analysis. The categories are represented by UML package diagrams to indicate that each package can be described in a more detailed way. These partial models will cover the requirements of each category.

The developed meta model will be capable to represent the following information for the management of construction projects:

- The definition of the building life cycle (phases) is the basis for the development of a construction project. Thus, the starting point for the construction network will be realised by the definition of the anticipated project phases on a general level (represented by a value chain).

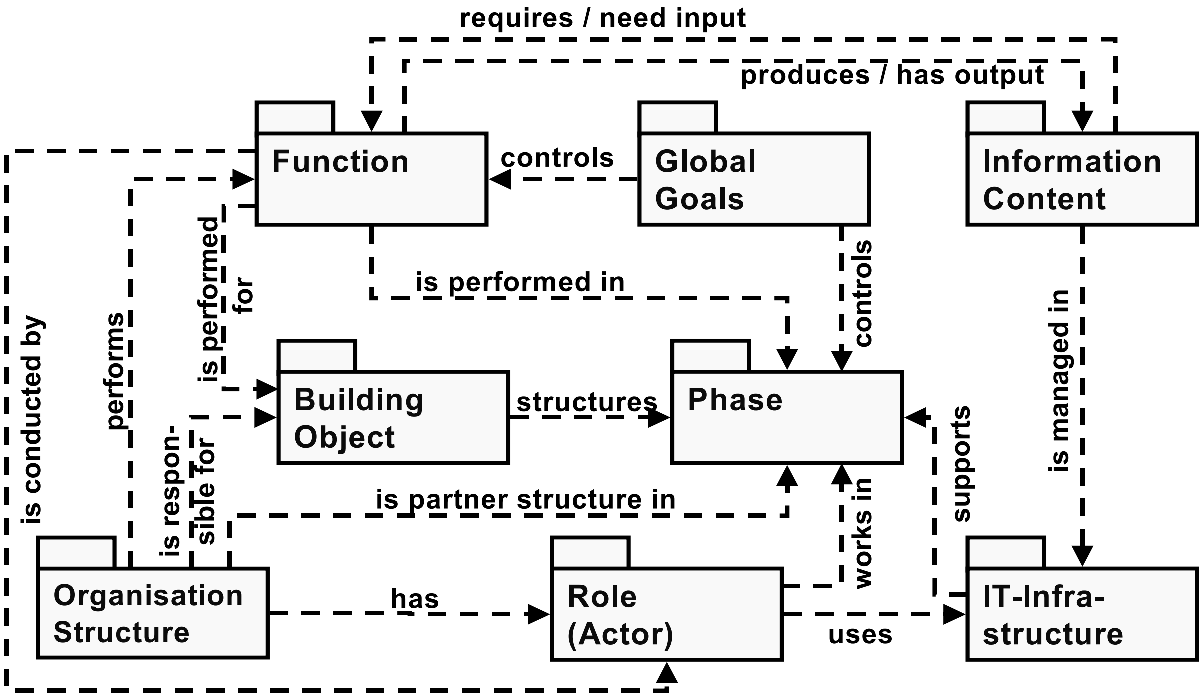

Figure 2: UML package diagrams of the proposed Construction Network Meta-Model

- Building objects provide the spatial and element structure of a construction. However, each phase can have its individual focus on the structure of the building objects.
- Functions are the activities that have to be performed within each phase. A sequence of functions creates dedicated building objects. One function can contribute to the creation of multiple objects.
- Global goals will be defined to control the performance of the functions within the different phases. Thus, a comparison of the nominal with the actual goals is feasible.
- A specific role is responsible for the conduction of several functions within a certain phase of the project.
- The category organisational structure specifies the type of the co-operation and the project partners. The partners of the organisational structure are linked with one or more phases. Furthermore, one or more partners of the organisational structure can implement different functions, are responsible for several building objects and have one or more roles.
- Information content describes the required input and produced output information for each function.
- IT-infrastructure specifies the global services and systems that support the different phases of a project. Each role can have access to the IT-infrastructure with dedicated rights. The information content will be managed by the IT-infrastructure.

For evaluation purposes the described *Construction Network Meta Model* has been partially implemented with the ontology editor and knowledge acquisition system Protégé[2] from Stanford University. By means of this editor the designed model can be exported as XML- or RDF-Schema[3] for further utilisation with other applications.

2.3 Instantiation of a Construction Network Meta-Model

In order to realise a construction network for a specific project, the classes and properties defined in the partial models have to be instantiated and the associations identified. The instantiation process is not performed randomly, but will obey certain legal, technical or organisational restrictions. Thus, the initialisation of a *Construction Network Instance* for a specific project can be controlled and supported by the employment of a sequence model. Such a model will assist the project partners to specify the content and relations of the different categories of the meta model in a structured manner. The employed sequence model should support loops, parallelism (AND-junctions) and restrictions (OR-junction). A more detailed description of a sequence model is given in Keller et al. 2005.

Figure 3 illustrates a simple example of a *Construction Network Instance*. The presented example has been developed with the Protégé system and displayed by its information browser Jambalaya. In this picture the arrows between the instances (grey rec-

[2] http://protege.stanford.edu
[3] Resource Description Framework Schema

tangles) gives an impression about the various relationships between the objects, even in such a simple example.

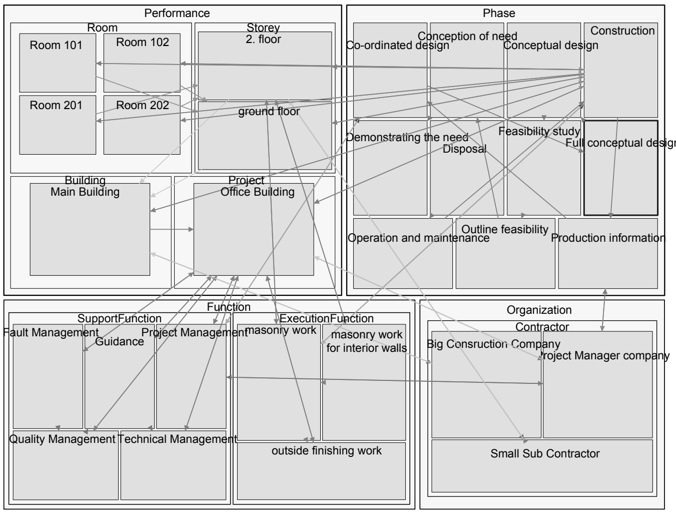

Figure 3 Construction Network Instance example

The realised *Construction Network Instance* can be stored in a common format, e.g. XML or RDF[4], to be accessible and manageable by a corresponding server. Thus, the *Project Network Instance* is an excellent knowledge base to perform various, complex queries on it. For example, it can be used for the identification of the responsible partner for a certain task at a building object (according to XSQL[5] notation):

```
<xsql:query> SELECT Organisation.Name
FROM ConstructionNetwork WHERE Project =
"Office Building" AND Floor = "second
floor" AND Function = "masonry work for
interior walls" </xsql:query>
```

3 USE OF CONFIGURABLE PROCESS MODULES

The specification of formalised business processes requires both, knowledge of the processes and knowledge of the modelling language. Thus, to preserve and reuse the generated knowledge the modelled processes should be stored in a reusable and coherent manner. Such reference information systems represent a special class of information systems. They are developed not only for one specific application context, but claim to be of general validity. The aim is to increase the economy of the information models by making the initial solutions available and adaptable. Thus they serve for the transfer of business knowledge.

In order to improve the access to the knowledge contained in reference processes, methods have to be developed, that support the adaptation of reference models for a specific application context [Becker et al. 2002]. The application context is represented by enterprise or project specific characteristics. The selection of the versions of the models will be conducted by means of these parameters.

Through the definition of a *Construction Project Meta-Model*, a standardised description for the project contexts has been achieved. Thus, the *Construction Project Instance* can be applied for the selection and initialisation of reference processes.

3.1 Design of a Process Module

Process modules are generally predefined for the performance of a certain bundle of activities and are adaptable for different project contexts. Each process module represents a logical element with distinct interfaces (Menzel 2003). These process interfaces are developed for a seamless integration of instantiated process modules into the existing workflow, defining all relevant input and output parameters.

Each process module will be identified by certain meta information that describes the parameters needed for its selection, initialisation and integration (e.g. project phase, organisation structure and output data). An example of a process module for construction processes is given in figure 4. The generic processes (modelled as an Event-Driven Process Chain) will be extended by parameters and information.

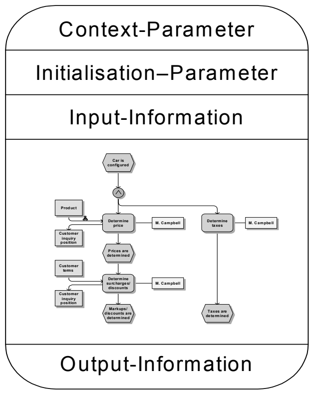

Figure 4: Process Module and its meta information

Context-Parameter define the situation required for the selection of a module

Initialisation-Parameter define the information that is needed for the customisation of a module for a specific project

Input-Information is the event/data, which is required to start the module

Output-Information is the result of a process module and thus the input for the succeeding process

3.2 Initialisation of a Process Module

In order to use the process module in a workflow management system they have to be transferred from the level of abstraction into the level of application.

[4] Resource Description Framework; W3C recommendation that defines a language for describing resources.
[5] combination of Extensible Markup Language (XML) and Structured Query Language (SQL)

That means, the process has to be adjusted to the context of the specific project. The *Construction Network Instance* will provide the required information for the selection of the appropriate module.

Example: The Construction Network Instance specifies the context (c): $c_1 = x_1$ and $c_2 = y_2$ (x_1 and y_2 are variables for the content of the context) A process module has the Context Parameters (CP): $CP_1 = \{x_1 \vee x_2\}$ and $CP_2 = \{y_1 \vee y_2\}$ Thus, the Process Module is capable for the execution of the process.

The process instances can be expressed in a common modelling language like BPML[6]. Thus, different workflow management systems are capable for the execution of the process.

4 IMPLEMENTATION

For the verification of the proposed approach 'errors and omission (E&O) management processes' in the building industry have been analysed. The E&O management involves several organisations of different size and roles, comprises main and supporting functions and requires a detailed structure of the building objects.

At present the coordination of E&Os, in particular its documentation and inspection on the building site, is little supported by software applications. Differences in format are common. Thus, seamless information processing of the fault data should be realised by the employment of mobile devices (PDA) in cooperation with already existing IT tools.

The development of the showcase has been started with a project analysis and the description of its conditions. Therefore, building sites of heterogeneous structure and with different organisational types were examined.

4.1 A Construction Network to support fault management

According to the analyzed projects a *Construction Network Instance* to support fault management processes is in general characterised as follows:

E&O management processes are part of the construction phase of a project. A common organisational structure in this phase is the 'general contractor'. A feasible organisational model is depicted in figure 5. It is composed of three different types of partners: a) building owner, b) general contractor, and c) subcontractors. The building owner contracts the general contractor for the installation of the complete or major parts of the building. The general contractor itself is a consortium of two or more companies and will assign several subcontractors for distinct tasks. Each organisation will have its own internal structure. For fault management all companies have to establish the 'quality manager' role.

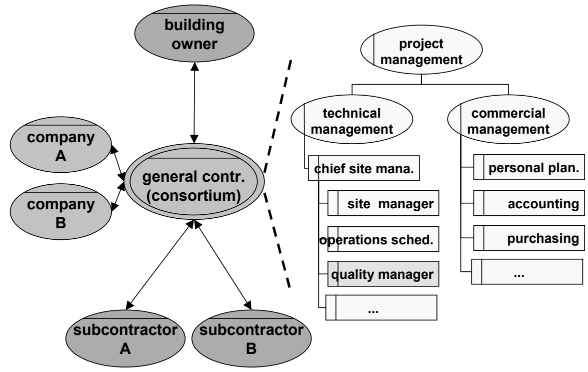

Figure 5: Organisational model

Each project is characterised by its individual structure for functions and building objects. This means that, the general contractor and his subcontractors have to conduct certain tasks (e.g. 'masonry works' or 'roofing') for specific items (e.g. 'interior walls in the basement' or 'roof of house IV'). These relationships will be described in the project specifications.

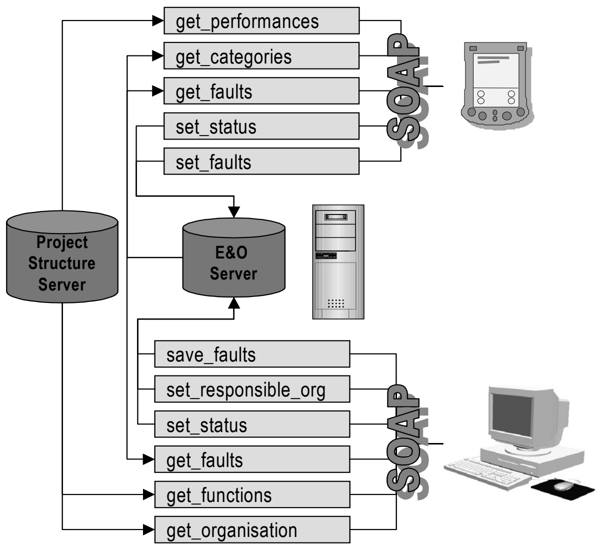

Figure 6: IT-architecture for 'E&O management'

For the management of E&O information a novel IT-infrastructure has been established. It will support the on-site E&O recording as well as its validation and management in the office. Therefore, the architecture indicated in figure 6 has been realised. Mobile and office application will access two servers that store the E&O and project information. Communication between application and server is realised by Web Services ('get' and 'set' functions in figure 6). Information exchange is handled by XML based SOAP messages. A data structure for the exchange of fault information has been developed.

By the use of Web Services different, already existing applications can be integrated into the fault management processes. Thus, each partner can participate in the project with its own application.

[6] Business Process Modelling Language

4.2 *Process Modules to support fault management*

At present no standardised model for E&O management processes has been realised. Regulations are handled in a project-specific way. Thus, various fault management processes have been analyzed and combined into a general process model. Subsequently, the general process has been decomposed into coherent process modules based on the methods introduced in Hofer et al. 2005. For the identified modules the meta information described in chapter 3.1 were specified. For example the quality manager of the building owner or general contractor can conduct the ‘fault recording’. A process module example is given in figure 7.

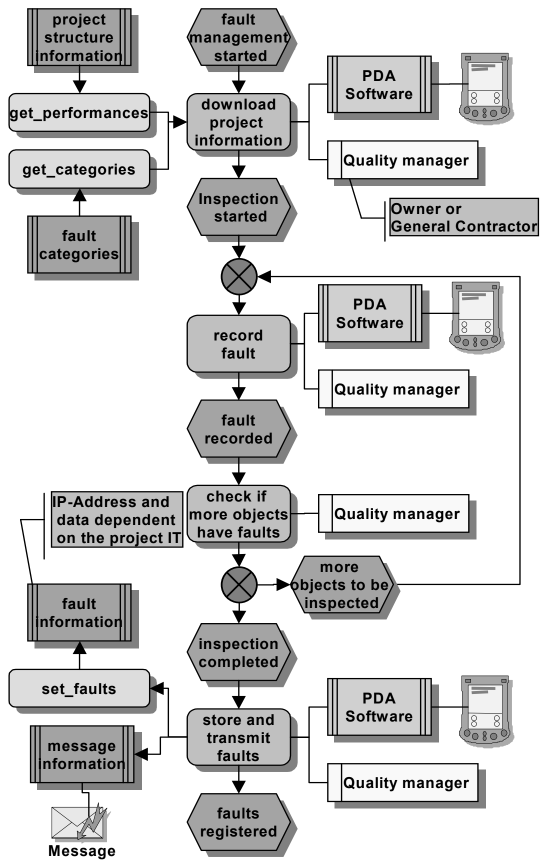

Figure 7: Process Module ‘fault recording’ (Event-Driven Process Chain)

For the above process module the identified meta information is:

```
Context Parameters
   Organisation Structure {General Cont.}
   Partner {Owner ∨ General Contractor}
   Role {Quality Manager}
   Phase {Realisation}
   Building Objects {all}
Initialisation Parameters
   IT-Infrastructure {Fault Server ∧ Pro-
   ject Structure Server}
   Information Content {Faults ∧ Mes-
   sages}
Interfaces
   Input {none}
   Output {Fault Notification}
```

For the instantiation of the process model it will be adjusted to the Initialisation Parameters and transferred into a common process execution language to be implemented in a workflow management system.

5 CONCLUSION

The aim of the paper was to present an approach for the support of inter-organisational construction project management. Therefore, a potential meta model, the *Construction Network Meta Model*, has been introduces. This model provides a schema for the definition of construction project specific constraints. It can employ various sources of reference data for the instantiation of a project specific *Construction Network Instance*. Such an instance can be used for the selection and initialisation of predefined process modules. Process modules are generally defining the activities necessary for the performance of a certain bundle of functions. Specific parameters and information have been identified to adapt the process modules for the context a certain project.

A common construction specific process, the E&O management process, has been analysed and qualified for the verification of the approach developed. Therefore, the required project context has been identified and the general process has been decomposed into coherent process modules.

This work has been conducted within the scope of the project ‘Architecture for Collaborative Systems’ (ArKoS). Within this project an holistic architecture for the management of inter-enterprise cooperation in construction is developed (Zang et al. 2004).

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