User Requirements Capture in Distributed Project Environments: A Process-Centred Approach

Peter Katranuschkov[1], peter.katranuschkov@cib.bau.tu-dresden.de

Alexander Gehre[1], alexander.gehre@cib.bau.tu-dresden.de

Raimar J. Scherer[1], scherer@cib.bau.tu-dresden.de

Jeffrey Wix[2], jeffrey.wix@aec3.com

Thomas Liebich[2], thomas.liebich@aec3.com

[1] Institute of Construction Informatics, TU Dresden, D-01062 Dresden, Germany
[2] AEC3 Ltd., 30 Northfield Road, Thatcham, Berkshire, RG18 3ES, UK

Summary

Efforts to define standards for representing AEC/FM data have been fairly successful. However defining a standard reference process model has not met with the same success. Yet almost every conceptual modelling or software development project starts by defining the business processes to be supported and the related requirements to be satisfied.

This paper describes a new process-centred methodology for user requirements capture developed in the ICCI project (IST-2001-33022). Its essence is in recognising user requirements and use cases in the context of the real construction process, identifying the actors and roles for each individual activity and associating these activities with information, communication and standardisation requirements on the basis of a formalised specification, named the Process Matrix. In the paper we outline the history of process matrix development, introduce the basic structure of the matrix and show how it can be further extended and refined. We present also a web-based software implementation of the developed approach, describe how it has been used in ICCI and outline further perspectives.

1 Introduction

Software and conceptual model development to date are typically performed in distributed fashion, in co-operation among several involved departments or organisations. This requires a sophisticated and well-organised development methodology, typically comprising the four stages requirements, design, implementation and testing.

The *requirements stage* includes capturing of business and software needs, and use case development and analysis. It influences quite strongly the complete development process, the bounded resources and the final results of a project. In detail, it can be decomposed into the following seven steps: (1) identification of actors, (2) identification of use cases, (3) constructing the use cases, (4) prioritising the use cases, (5) detailed specification and description of the use cases, (6) formalising use case descriptions, and finally, (7) structuring the use case model.

The complete requirements capturing process starts more or less with an empty sheet of paper to be filled in from the knowledge of use case developers and end user expertise. There exists software supporting this process, e.g. *Rational Rose* from Rational Software, but it focuses mainly on formalised diagramming methods such as IDEF0 (NIST 1993) and UML (Booch et al. 1999), and their further exploiting to provide a transition to the software design and implementation stages. Actual requirements acquisition and synthesis are only weakly supported.

For example, the IDEF0 approach used in the EU projects OSMOS (Wilson et al. 2001) and DIVERCITY (Shelbourn et al. 2001) has provided adequate results in these projects, but the acquisition process has been long, and the results not readily adaptable to software development. Therefore in both projects an enhanced methodology has been developed, enabling transition from IDEF0 to more detailed UML based formalisation. However, the UML approach, applied e.g. in the EU projects eConstruct (Steinmann et al. 2000) and ISTforCE (Turk et al. 2000), has also not been fully adequate for a coherent downstream treatment of specific AEC scenarios developed by end users.

From these and other studied cases it can be concluded that steps 1 to 5 of the outlined requirements capturing process lack an adequate methodology supporting developers with predefined actors and process knowledge for the recurring typical processes in the construction industry. Starting from scratch every time, without appropriate software support, does not only waste a lot of resources but often produces ambiguousness and hinders reuse of earlier findings.

The main reason for this undesirable situation is that there is no harmonised specification approach to address industry requirements to ICT. Currently, requirements are not well articulated and are often poorly understood. As a result, there are many gaps between industry needs and software development. New applications are more often driven by technology push than by actual market demand.

Therefore, recently an effort was undertaken to collect, synthesise and consolidate end user requirements and use cases from past research projects in order to provide a harmonised set of requirements within a uniform reference model having the potential to overcome known shortcomings. This effort led to the development of a new process-centred methodology for requirement capture, named the **Process Matrix approach**. It is the focus of the presentation in this paper. The reported research is largely based on results achieved in the frames of the EU project ICCI (Katranuschkov et al. 2002a,b; Katranuschkov et al. 2003).

2 Related Work

The idea of establishing a generalised conceptual *information model* that can capture project data within building construction has been well documented over many years and is now approaching fruition through the IFC model of the IAI (Wix and Liebich 2001).

More recently, there has been a growth of interest in the idea of developing a counterpart *generalised process model* (Björk 1999). In some cases this has been in support of proposed new, non confrontational methods of working within the industry, in others it has been seen as a useful basis for the specification of high-level requirements, or for identifying gaps in the coverage of conceptual information models and for creating road maps to fill them.

Requirements have been collected and analysed by many researchers in the last decade. Comprehensive analyses are provided by large research and industry efforts like Building IT 2005 (Howard 1996), the EU projects ELSEWISE (ELSEWISE, 1998), OSMOS (Wilson et al. 2001) and others. Different aspects have been focused, and various approaches have been tested. However, all these approaches lacked a strictly formalised basis for downstream refinement of requirements for practical development purposes in construction IT. Even within the ISO STEP standard, where activity modelling is a mandatory first stage of the AP development process, there is no prescribed standard methodology for requirements capture (cf. Fowler 1995).

Such a methodology can be achieved by adopting a *process-centred view* where activities can be coherently associated with information and communication processes and the respective ICT standards to support them. This is the view taken in the development of the Process Matrix approach. Its major concepts are detailed in the following chapter.

3 The Process Matrix Approach for User Requirements Capture

The Process Matrix approach is the result of critically reviewing and merging the content of nearly 100 process models to define a simple formal method for identifying atomic process concepts that should be universally applicable. It combines aspects of the *Generic Process Protocol* developed recently in the UK (Kagioglou et al. 1999) with identification of specific processes and requirements to processes that may be further subject to UML activity diagramming, thereby providing a framework within which sets of reference processes can be identified and from which those that are relevant to individual construction or software development projects can be derived (thus defining project processes). Whilst the Process Matrix is not a process model in itself, by providing a standardised list of actions it can become a reference source from which process models, and potentially also project schedules, can be developed. In this sense, it is complementary to standardised information models for the industry. The need for such a reference has been endorsed by the International Technical Management committee of the IAI at its meeting in Singapore in October 2003.

3.1 Development History

The origin of the Process Matrix was in work carried out for the UK National Economic Development Office when the importance of understanding process in the context of data exchange for building construction emerged. Most design work at that time was carried out according to a Plan of Work that separated work into a number of stages and identified some key actions at each stage (Wix and Cornick 1990). In studying the Plan of Work, it became clear that the processes outlined were too coarse for use in control of data exchange and so a preliminary effort was made to see how they could be further broken down for this purpose. This effort contributed the basic action breakdown approach for the Process Matrix.

Work on a harmonised approach to process and requirement capturing continued throughout the 1990s with the major focus on the Generic Process Protocol. In the EU project ISTforCE an effort was undertaken to provide a comprehensive process model in support of the developed general interoperability architecture and services. A number of existing process models were studied which led to the following conclusions (Wix and Liebich 2000):

- there was no cross referencing or common understanding between published models,
- process model development was usually not complete to a level where function definition could be properly addressed,
- it was not possible to define a single process model that could cover every eventuality that could occur on building construction projects.

A study was also conducted of available process modelling methodologies. From this, it was concluded that there was no single methodology that could fulfil the higher-level requirements of a process approach that could handle the widespread nature of building construction.

As a result of the ISTforCE work, the first Process Matrix was born. It absorbed the results of 25 existing process models together with input from industry into a set of simple tables that provided a library of possible processes that might be used on a project. Further work has been carried out so that the Process Matrix now absorbs and integrates the content of over 100 other models, with others being added as they are identified. Since the original version, the Process Matrix has also been extended to cover other action related information such as data, standards for transfer, classification of outputs, communication paradigm and file types concerned, etc.

3.2 Structure of the Process Matrix

From end user viewpoint the Process Matrix appears as a simple table that brings all stored information concerning a reference process together in *one line*. This approach has been adopted because experience shows that industry end users are not particularly familiar with formal modelling notations. However, they are familiar with, like, understand and respond to the tabular approach of the Process Matrix.

The basic form of the Process Matrix is shown in Figure 1 below. As will be shown in the next section, this general structure can be expanded by inclusion of further tables enabling the representation of information, communication, standards requirements and more.

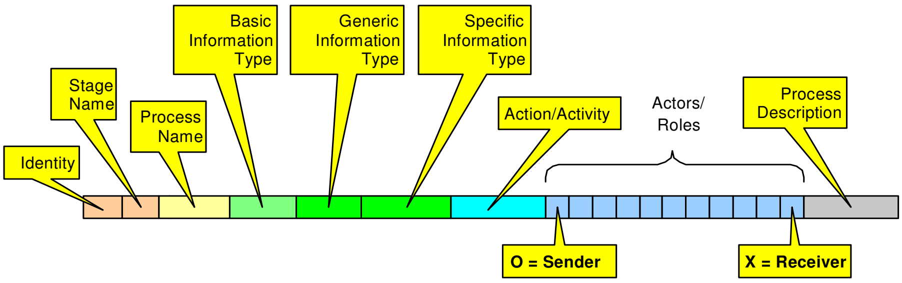

Figure 1: Basic structure of the Process Matrix

Actions and activities at all levels are termed *process*. The *Identity* field asserts the identity of each process within the matrix. It is a number that should also serve as primary key in a database implementation of the matrix.

Each row in the matrix represents a single business process and the information communication shows the end result and who is supposed to use that result in subsequent processes. Each process may be further broken down into sub-processes or detailed by using a diagramming approach such as UML activity diagrams. Processes are explicitly represented in the matrix by their *Identity* key (*Process_ID)*, *Name* and optional *Description*. They are defined as being either actions or activities in accordance with the UML specification (cf. Booch et al. 1999).

Normally, high-level processes will be further decomposed into sub-processes at more detailed representation levels. There is no specific provision for that in the Process Matrix but through the defined method for generating process IDs sub-processes can easily be sorted and tracked.

Processes are organised by project stage whereby the organisation of project stages set down in the Generic Process Protocol is used with some extensions. This provides a framework for carrying out any construction project. It considers that the lifecycle of a project development is described in terms of four main stages, i.e. pre-project stage, pre-construction stage, construction stage and post-completion stage, with 11 associated sub-stages (phases).

A process has a typical formalisation of communication indicated in the matrix, e.g. 3D model, 2D drawing, cost plan, schedule, list etc. This is covered by the attribute *basic information type*. Information in a process is received from one or more predecessors (as a prerequisite for executing the process), created and exchanged within the process, and passed over to subsequent processes.

However, information requirements of processes have also many other aspects that need to be considered. In the basic form of the matrix shown on Figure 1 two of these aspects are explicitly represented, namely the *generic information type* (related to some classification system) and the *specific information type* (enabling association of information items to secondary, more detailed classification items). Classification of information items is largely adopted from the IFC model which provides two different ways of classifying objects – a *classification reference*, where only a light-weight classification notation item is given by an identification string and eventually a reference to a classification system, and a *classification notation* which provides a possibility for more comprehensive description by appropriate association to a respective classification facet or table.

Communication occurs between the participating actors. Predominantly, actors are identified by discipline in most current models. Within the Process Matrix, it is considered that communication occurs between actors fulfilling *roles*. That is, the same actual actor may fulfil multiple roles – communication at the role level is the aspect of interest.

3.3 Extensions

Three major extensions are currently defined to complement the basic Process Matrix. Their purpose is to provide additional details on the requirements to a process that can be seamlessly incorporated in the matrix. If used, they can be directly associated to the basic matrix via the *Process_ID* key. In this way the principle that each process should always be represented by one row of data is preserved. However, for better structuring, the specification of information types was moved from the basic matrix into the information requirements extension.

3.3.1 Information Requirements Extension

The objective of this extension is to identify the actual data communicated in a process that can serve as guideline for the definition of more specific requirements for a software system or tool intended to support that process. In addition to the basic, generic and specific information types, it introduces two new fields: *data model* and *data content*.

The *data model* field identifies an underlying schema according to which the actual information communicated in the process may be represented. This must not necessarily be a product data model, for other types of information similar requirements can be represented as well. That issue may not be so important for a single process but it can expose potential problems in a larger use case. For example, in a particular construction project processes may be defined that communicate documents using different underlying models which are incompatible to each other (or the virtual organisation does not possess tools enabling their mapping). The matrix can greatly help to reveal such problems in time.

The *data content* field provides a description of the actual needed content. This would typically be done in textual form but, in the case of a product model, it would be preferable to use normative names of objects or conceptual schemas.

3.3.2 Communication Requirements Extension

The objective of this extension is to identify the 'technical' aspects of communication between the actors in the process, such as the model of the communication process (e.g. client/server), the network protocol (e.g. FTP or HTTP), the exchange/messaging format used (XML, HTML, IFC exchange file) etc. It can also capture requirements for more advanced communication techniques such as SOAP or WSDL.

The components are structured in three groups: *communication model*, *communication protocol* and *exchange format*. They provide individual (sub)columns for pre-defined enumeration lists, and an additional text field (*MIME type*) enabling the provision of more detailed specification of the exchange format (similar to the generic/specific information type classification). For these enumerations three different values are used: *B* = *Binding* (meaning that the respective type is binding for the process), *O* = *OneOf* (meaning that there is a choice of different possibilities, but the one chosen should be the same in the whole use case), and *S* = *Several* (multiple options).

3.3.3 Standards Extension

The standards extension enables an assessment to be made of the likely standards (formal or otherwise) that may be applied to a process. Standards referenced are those relating to information communication and identify the support of a view of a model for that particular business process.

Basically, requirements or recommendations to use an ICT standard can be associated to several cells of the matrix as follows:

- Process - AEC codes and regulations
- Basic information type - Meta data standards
- Generic information type - Classification system / standard
- Data model - PDM / EDM / Data model standards
- Communication protocol - Communication standards, e.g. TCP/IP
- Communication model - Comm. model standards, e.g. Client/Server or P2P
- Exchange format - Data exchange / sharing standard, e.g. SPF.

These links can be multiple, i.e. there may be several standards that are suitable for a certain aspect of a given process.

All standards are described in a single *Standards* table in the same way as the Information and Communication Requirements. To enable association of the above listed aspects of process with this table, the basic matrix can be expanded by 6 additional columns, in each of which multiple entries (lists) are possible. Each such entry should be comprised of zero or more references to standards, internally using the *standard IDs* as foreign keys.

Figure 2 below shows the updated structure of the Process Matrix with all three optional extensions.

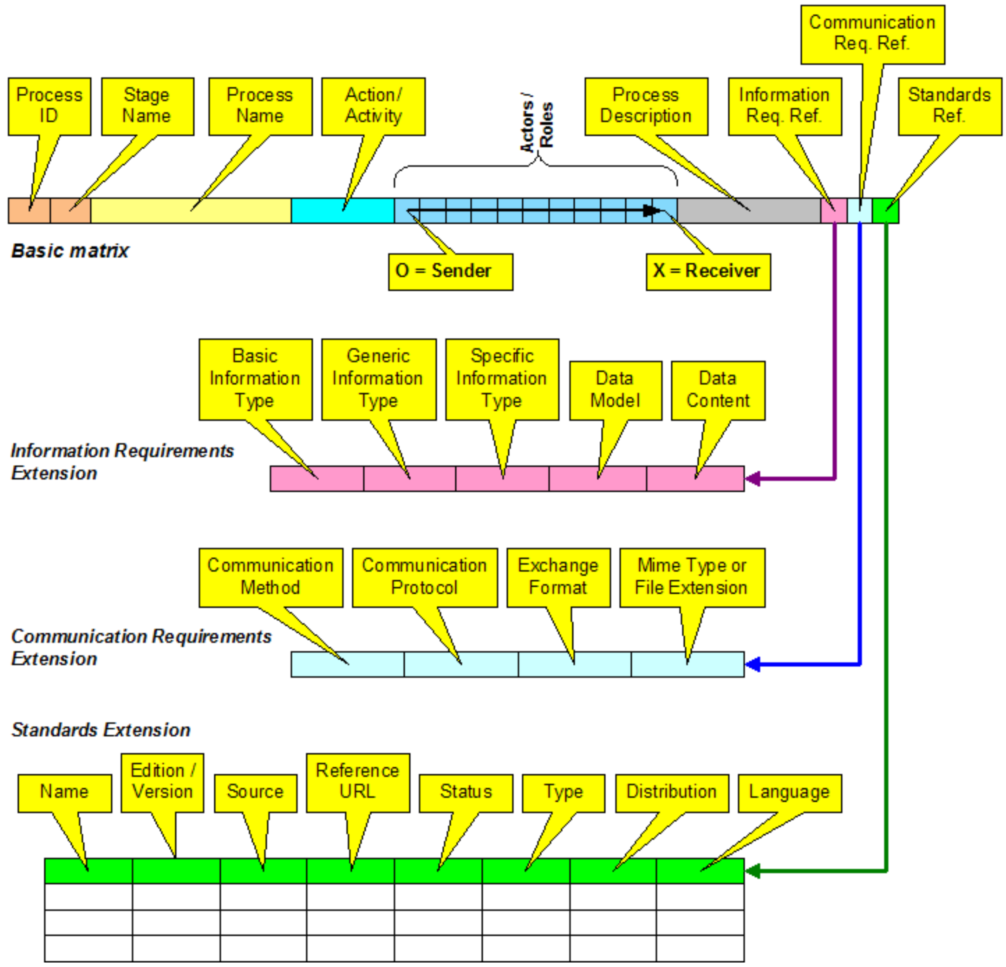

Figure 2: Principal structure of the Process Matrix with all developed extensions

4 Web-Based Implementation of the Process Matrix

Since most large software, modelling and standardisation efforts are performed by virtual organisations comprised of a number of partners, teamwork, cooperation and distributed concurrent development are issues that need to be duly considered. Consequently, IT support to the process matrix method has to be provided as a service that is fully accessible on the Internet, preferably via a standard Web Browser. This has been seen as a major design requirement in the implementation of the process matrix application **ProMAP**, shortly described below.

In summary, ProMAP is a version of the Process Matrix that is visible via the web. It enables process descriptions to be created from the Process Matrix for individual projects. In addition, it allows users to add processes that are specific to their projects and to edit those that have been sourced from a reference list of generic processes. All information that is shown in the basic tabular version of the matrix is visible in ProMAP in a slightly different configuration. Information, communication and standards related extensions to the Process Matrix can be selected for visibility or suppression.

The application is comprised of two major components: (1) a Web-based GUI utilising the *Java Server Pages* technology via a *Tomcat Server*, and (2) a relational database storing all pre-defined reference processes as well as process specifications created by end users.

The user accesses ProMAP by a standard Web Browser providing interactions based on hyperlinks and HTML-forms for input and editing of the data. The navigation bar to the left of the screen enables users to log in to projects that have already been created or to create new projects for which a process model is to be derived.

Process and requirements capturing is supported in two ways. On the one hand, a new process can be created by entering a fresh set of mandatory data (process name, actors, basic information purpose etc.) and then storing the new process into the ProMAP database (Figure 3). On the other hand, processes can also be adopted from a pre-defined **Reference Process Matrix** which is a permanent part of the database (Figure 4).

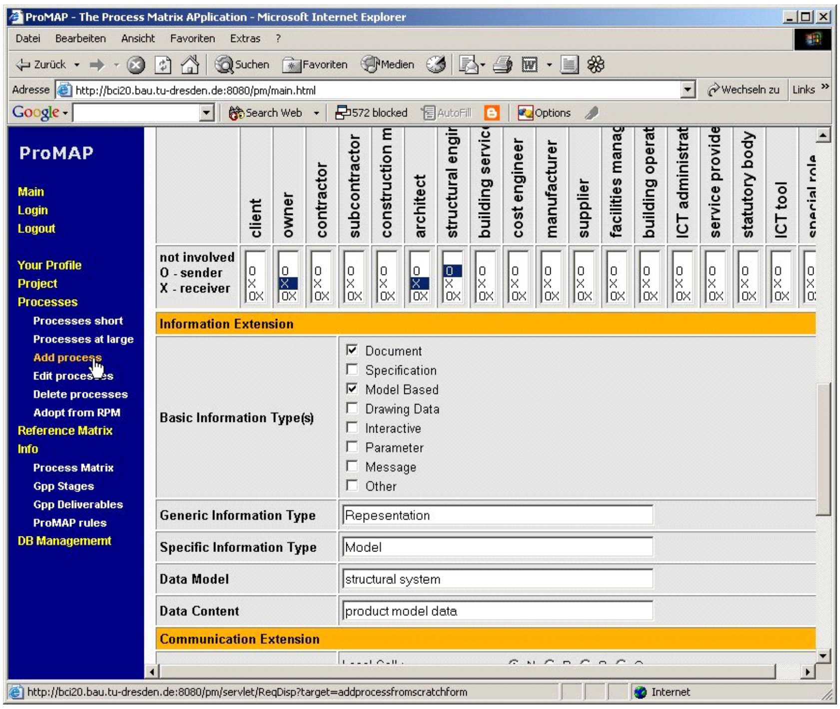

Figure 3: Adding a process in ProMAP

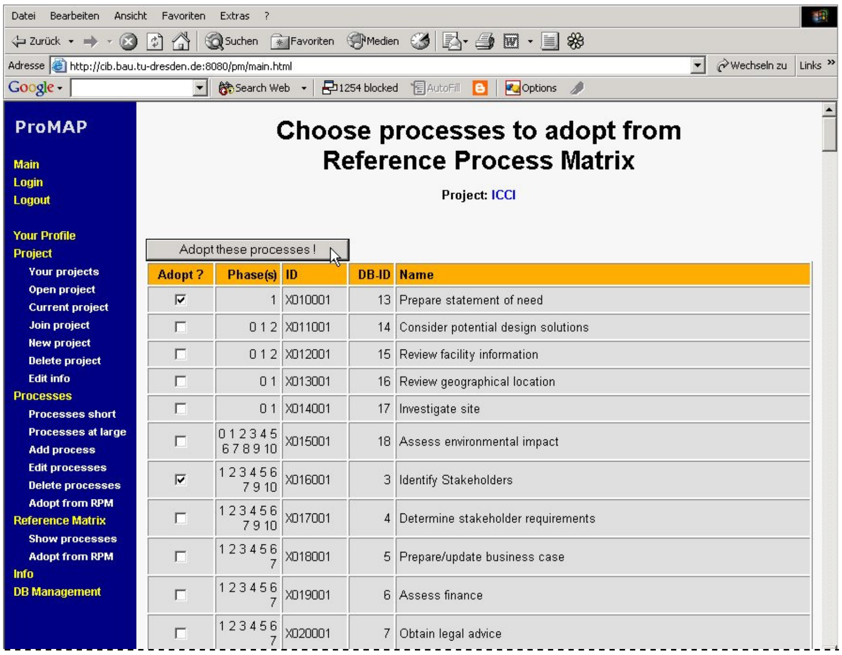

Figure 4: Adopting processes for a specific project from the pre-defined Reference Process Matrix

After initial definition, a process can be elaborated in detail e.g. by activating the information / communication / standardisation requirements extension sets. In the same way, generic processes imported from the reference matrix can be edited, adjusted and extended to suit particular project needs.

Beside the capturing of processes and related requirements, an important feature of ProMAP is the provision of a *range of sorted views* so that coherencies, clusters and gaps can be identified and (indirect) requirements derived. Figure 5 provides an impression of the manner of defining processes in the Reference Process Matrix. In the same way, any other *process matrix instance* can be defined and presented.

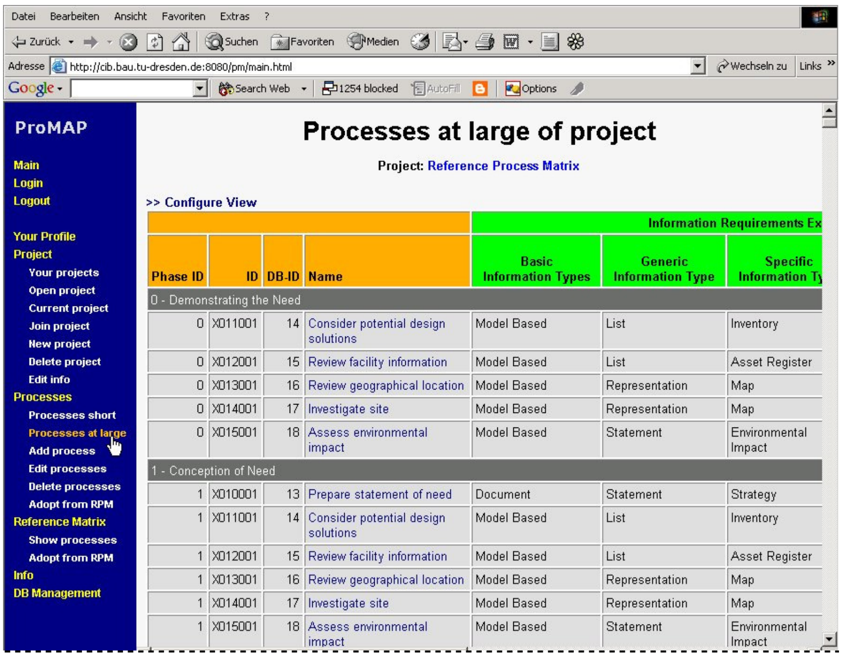

Figure 5: Screenshot of pre-defined processes in the reference matrix listed in detailed form

In addition to the process matrix contents, the concept of ‘gates’ from the Generic Process Protocol (cf. Kagioglou et al. 1999) is implemented. Furthermore, a planned extension to ProMAP will provide initial input to further process elaboration in UML activity diagrams, as a transition mechanism to process and requirement oriented software development.

A very important feature of ProMAP is its *multi-user capability* enabling truly distributed work on requirements and process specification. This is achieved by organising the work within ProMAP in distinct *project* and *work spaces*. Thus, each user always works in his own private workspace which stores his profile data, access permissions and active projects. In contrast, projects are typically not assigned to individual users but can be accessed and used by an arbitrary large number of actors. In other words, a workspace is personal, and a project is a community issue. The main thing to understand about the ‘project’ concept is that it associates exactly one process matrix instance with all users that have joined the project. Access to the database is achieved via short transactions and conventional write locks.

5 Use of the Process Matrix in the ICCI Project

There are various business cases in which the Process Matrix can be useful. Within the frames of the ICCI project the Process Matrix approach was used to collect and synthesise processes from the member projects and other studied development efforts, generate appropriate views, perform a gap analysis, and from that, derive conclusions and recommendations.

5.1 Gap Analysis

Processes were collected using a uniform *form template* and the matrix was populated and processed with the help of ProMAP. The *gap analysis* aimed at understanding the business requirements for which process and data model provision has already been made and therefore, where attention is required in future development and standardisation efforts. This was performed by detailed queries on the ProMAP database. Figure 6 below provides an example showing how the data from more than 250 processes captured in the matrix were synthesised and analysed from different viewpoints. The ICCI report D12-2 (Katranuschkov et al. 2002b) provides 22 such diagrams. These can easily be further extended, if other aspects and relationships need to be examined. For example, in the EU project prodAEC (IST-2001-32035) the use of data exchange standards was examined using virtually the same approach.

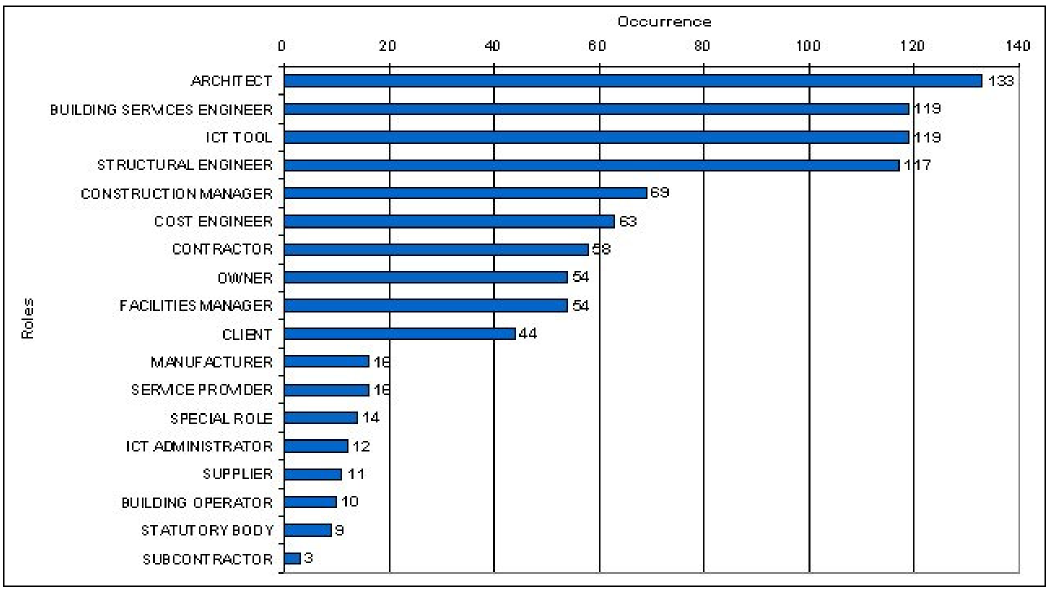

Figure 6: Overall distribution of actor roles in the examined AEC/FM processes

5.2 Analysis of Existing Process Models

In a similar manner, currently known process models from research and industry have been classified on high level and analysed with regard to their capabilities to identify the degree of process coverage in the global e-Business context of AEC. Figure 7 provides a summary diagram of the studied process models.

This specific view from the matrix is arranged along the major axes *stage/phase* and *actor role* (synthesised here to broader domains). The relevance of a particular process model to a specific stage and domain is denoted by a circle and the acronym of the model, whereby light coloured circles indicate small models, covering only a few specific, typically application-driven processes, darker circles indicate medium size models, and black circles indicate large, fairly comprehensive coverage of the referenced stage and domain. Whilst it can be argued that such a classification is (inevitably) subjective, it provides a harmonised summarising view of contemporary process modelling research and achievements and clearly shows gaps where more efforts are needed, and overlaps where harmonisation/unification of approaches appears a major issue. More details to that diagram can be found in (Katranuschkov et al. 2002b).

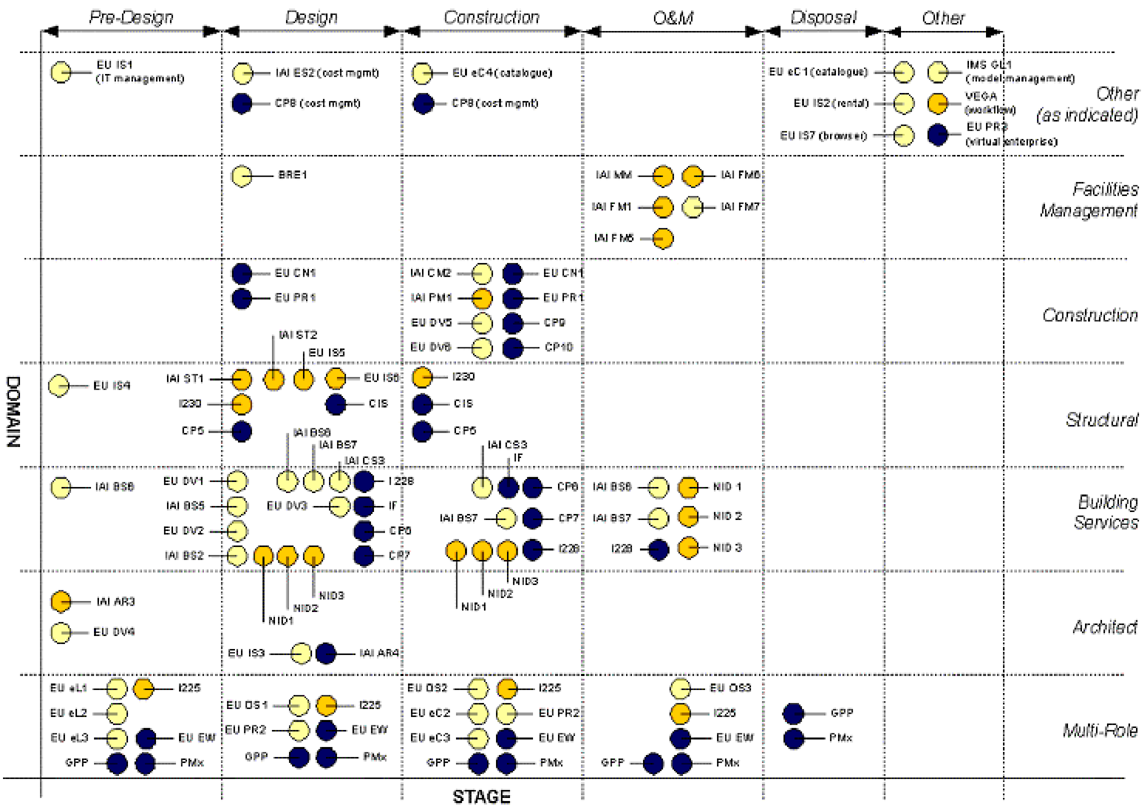

Figure 7: Process model scatter graph

6 Further Possibilities for Process Matrix Use

Whilst the process matrix approach has been developed primarily for user requirements and process capture in software and conceptual model developments as well as for performing gap analyses of studied past efforts, it provides also a range of further possibilities. Some of these are shortly outlined below.

- Use of the Process Matrix to support IFC model development
  There are a number of entities in IFC 2x (Wix and Liebich 2001) that relate to the ideas within the Process Matrix and these can be used to define a subset or view of the IFC 2x

model that can uniformly support the basic matrix, a matrix derived process model, and a matrix derived project schedule. Work in this area has begun within ICCI and is now continuing in conjunction with IAI (Wix et al. 2003).

- Cyclic processes
  Many design activities are repetitive, i.e. the range of activities carried out at each cycle of the design process (feasibility, conceptual, detail, production) is broadly similar although the granularity of information at each stage is finer. Thus, whilst a designer may be dealing with space elements during the conceptual design stage, he may be dealing with the building fabric elements bounding the spaces at the detail design stage. This cyclic nature of process during design could be captured within the matrix providing that the granularity of data as design progresses is also captured.
- Process ontology
  The Process Matrix is, in essence, an ontology of process for building construction. As such, it is proposed that additional approaches to representing the matrix are explored. In particular, the meta model from ISO/PAS 12006-3 (2001) is seen as one possible representation form whilst the Web Ontology Language (OWL) defined by the W3C is another possible approach and one that can lead to further work on inference and reasoning over process.

7 Conclusion

Although the idea of the suggested approach is in fact quite simple, its development has identified great potential. The range of possibilities that can be mapped to it have only just started to be explored and it is considered that there is much more that will be discovered as it is further developed. In particular, it offers a powerful capability for identifying industry requirements in e-Business. This has been demonstrated to some degree by its use as in understanding the gap between current developments and future requirements in terms of information model development (necessary for both e-Commerce and project data integration).

The interlinking of reference processes with applicable standards can provide for better identification of standards supporting critical business processes, standardisation gaps within single processes, and the overall standards collection needed to leverage the full potential of standardisation. In fact, the Process Matrix is independent of any particular process approach, whether it be national plans of work, contract driven process maps or industry led approaches. In this sense, it has the potential to act as a focus for defining more global and more strictly formalised approaches to process.

8 Acknowledgements

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