ADVANCED DOCUMENT MANAGEMENT SOLUTIONS FOR THE CONSTRUCTION INDUSTRY: THE CONDOR APPROACH

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Abstract: the paper gives a comprehensive overview of the European Esprit Condor project. The project provides a migration path from document-based to model-based approaches to information representation and structuring. The paper first presents the approach that was adopted to describe the business processes and document management practices of the Condor project end-users, and also to capture the requirements of the Condor system. The chosen approach made use of the IDEF0 and UML (Unified Modelling Language) methodologies. A Strategy towards the integration of the electronic document management systems used within the Condor project is then given. The paper also includes a comprehensive description of the overall Condor models that support the proposed system. Finally, a brief description of the business process re-engineering activity within Condor is given. The project is ongoing and supported by a user interest group, which involves representatives from a variety of non-construction industry companies all over Europe.

Keywords: Electronic Document Management, Object Modeling, Computer Integrated Construction.

1. INTRODUCTION

The nature of the construction industry is such that virtual teams are often brought together for projects before being broken apart again on completion. Organizations and individuals participating in a team bring their own unique skills and resources, which may include proprietary applications and data.

In the design and construction process diverse and complex information flows between actors. This information is mainly conveyed using documents. The latter need to be highly consistent in order to provide a reliable basis for actors to perform their design, construction and maintenance activities. Document management has become a crucial issue within modern construction companies. The various solutions proposed by some software vendors revealed to be unsatisfactory, to a point where many leading construction organisations, with an advanced IT department, have undertaken the development of their own tools and solutions to support the production and maintenance of project documents. Even though such proprietary tools provide many helpful facilities, including support for document storage, retrieval, versioning and approval, they don't handle any semantics of the information being processed and therefore remain limited in their support of the end-user. In fact, construction project data and documentation (including full specification documents) constitute two fragmented information sectors where compatibility and interoperability are mostly needed. Moving these pseudo-sectors closer together to support construction project documentation as part of the life-cycle of the building product is becoming an actual and urgent topic for standard bodies and industry alike.

In order to pioneer a solution, a consortium driven by construction end-users (Kvaerner Construction from UK, OTH from France, and JM Bygg from Sweden) was set up. The consortium is currently collaborating within the frame of the European (ESPRIT 23 105) Condor project. It is investigating a new model-based - as opposed to file-based - approach to

document production and management, based on recent IT developments. One aim is to demonstrate the genericity of the approach, and its applicability across industries. The paper, based on the Condor research, presents a means of bridging the gap between the traditional document-centered and the proposed (model-based) approaches to project information structuring and representation. Robust models supporting this transition have been developed, together with a prototype implementation which demonstrates a pro-active use of document management and information management techniques in a collaborative multi-actor environment.

2. DOCUMENT MANAGEMENT IN THE CONSTRUCTION INDUSTRY

The business processes and the document management practices of the three end-users involved in the Condor project have been analyzed [1]. This analysis was then generalized to the whole industry. It revealed that present document management relies to a large extent on manual methods, although the production of documents is mainly done using computers. However, in recent years, many leading construction companies (including the ones involved in Condor) have enforced the use of electronic document management (EDM) systems to support effective and consistent management of the entire documentation produced and used in a project. These systems are now introduced in the construction industry much like CAD (Computer-Aided Design) was introduced about two decades ago.

Despite some minor differences, the analysed EDM systems offer similarities across organisational boundaries. An example of this exists in document categorisation, archiving, retrieval, versioning and approval. The services provided by these EDM systems are being used as a basis to define the Application Programming Interface that will support inter-working between these legacy applications, as described in chapter 4. The documentation managed by the various EDM systems can be divided into three main categories, produced by different actors:

- Common general information, produced for the industry by material vendors.
- Company specific general information.
- Project information.

Kvaerner Construction can be considered as a pioneering user of EDM systems in the construction industry. Figure 1 describes the environment in which their EDM system is used, and how it supports their business processes. Kvaerner use a document controller to set up an electronic hub for all parties to manipulate, pass and distribute documentation. The document hub provides a collection of services. For instance, it maintains some form of drawing control that keeps track of drawing information, complemented with various functions, including, approval, receipt acknowledgement, and document distribution. The hub also manages correspondence (which handles incoming and outgoing mail) and an information control service (which handles information requests from the system).

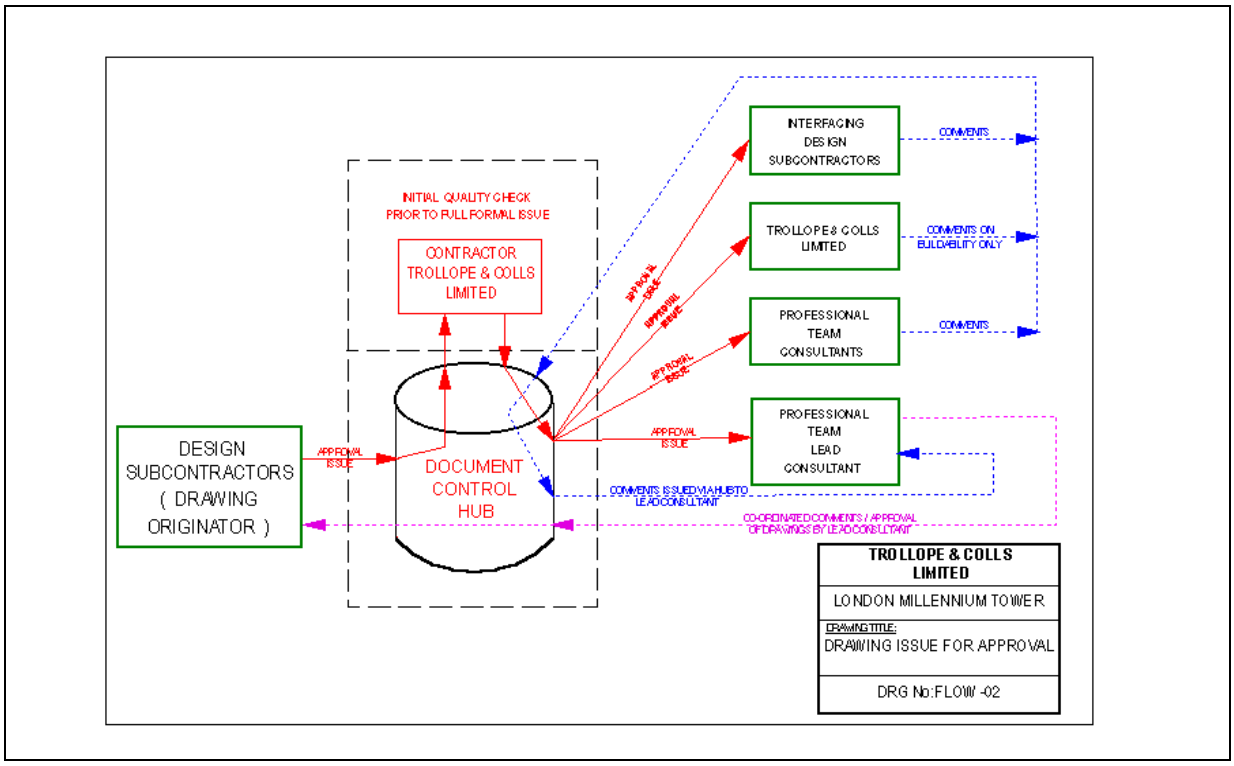

Figure 1. An example of Document Flows in Kvaerner's EDM System

The overall analysis of current document management practices within the three construction companies involved in Condor revealed the following limitations inherent to their current system and work methods:

- Every partner within the project must have the same document handling software to be able to communicate effectively with the project database.
- All designers must use the same commercial CAD software. The latter does not support electronic document management.
- Security is not easy to implement as for printed documents. Electronic document management requires improved user authentication and data protection.
- The EDM system is, most of the time, not integrated with existing proprietary and commercial applications within the company (e.g. financial, and property management systems).
- Most end-users in the construction industry are not computer literate. EDM systems lacking user-friendliness, or used in a cumbersome environment (e.g. network communication problems) discourage the user from using the EDM system.

3. CAPTURING THE REQUIREMENTS OF THE CONDOR SYSTEM

The Unified Modeling Language (UML) methodology [2] was chosen to specify, visualize, and document the underlying artifacts of the Condor system. A use case diagram has been specified and detailed to describe the Condor system in use. A Use Case describes a specific way of using a system. The identified Condor use cases describe the functionality performed by the Condor system as a result of a request from an Actor. They provide a way to capture the requirements about the system, communicate with the end-users and domain experts, and test the system. The main Use Cases identified within the Condor system include:

- Add information to distributed system: this use case describes the process of adding a document or a piece of information to the Condor registry. Once referenced in the registry, the document is then accessible to all authorized users of the Condor system.
- Browse Condor Information: this use case describes the process of browsing the information held by the various information providers registered with the Condor system. The shared information (e.g. documents) is referenced in the Condor registry.
- Retrieve Information: this use case describes the process of retrieving information held by an information provider via the Condor registry.

We have then described in detail all the transactions involved in implementing every single identified use case. This was done via interaction / sequence diagrams. Then, based on the analysis of the business processes and document management practices of the Condor end-users within the context of a construction project, a generalized IDEF0 document management activity model was proposed. This model describes the generalized document management activities taking place in the design and construction process.

The use case approach from UML bears some similarities with the IDEF0 approach, in the sense that they both aim at providing a basis for the understanding, definition and capture of the requirements of the system to be developed. They proceed, however, differently. UML looks at the different ways of using a system by specifying all the proposed system use cases. Every single use case is detailed via a sequential description of the interactions between the different artifacts involved within it. IDEF0 provides a top-down hierarchical description of a process activity model, along with information / material flows between those activities. The latter is described via Input, Control, Output and Mechanisms between activities. Both approaches are complementary and are used in conjunction in the Condor project, as indicated in figure 2.

Figure 2 illustrates how IDEF0 is used in conjunction with use cases and sequence diagrams from UML. The IDEF0 document activity model presents the scope, context and construction environment in which the proposed Condor system is used [1]. It details the "Do building document management" activity. It includes the following activities:

- *Check, classify and define linking for documents:* this activity represents the authoring process of a document. It is supported by a document processor (e.g. CAD package for drawings, or word processor for written documents). The document being authored might not be visible, at this stage, by the EDM system.
- *Register, import and link document:* this activity represents the registration process of a document. Once registered, the document becomes accessible to authorized users.
- *Search document:* this activity describes the activity of searching for specific documents managed by the EDM system.
- *Retrieve reference, relationship data and document:* this activity describes the process of downloading a document using the EDM system. Figure 2 illustrates the fact that this activity is described by a UML use case and sequence diagram. The interaction diagram in figure 2 describes the process of retrieving information from an information provider. The user passes the ID of the document they want to retrieve. The registry requests this document from the information provider that holds the document. The registry passes back the requested document to the person who originated the request.
- *Administer and manage document archive:* this activity represents on the one hand, the pure administrative activities of the EDM System, and on the other, the management services that the document management system provides for the users. The administrative activities include defining the classification templates and the documentation structures,

performing backups from the document archive, producing statistics from the system in use. The document management services may include the following activities: automatic notification of users for new imported documents in the system, automatic distribution of imported documents (according to document reference / distribution information), and copying, moving, deleting of documents in the system.

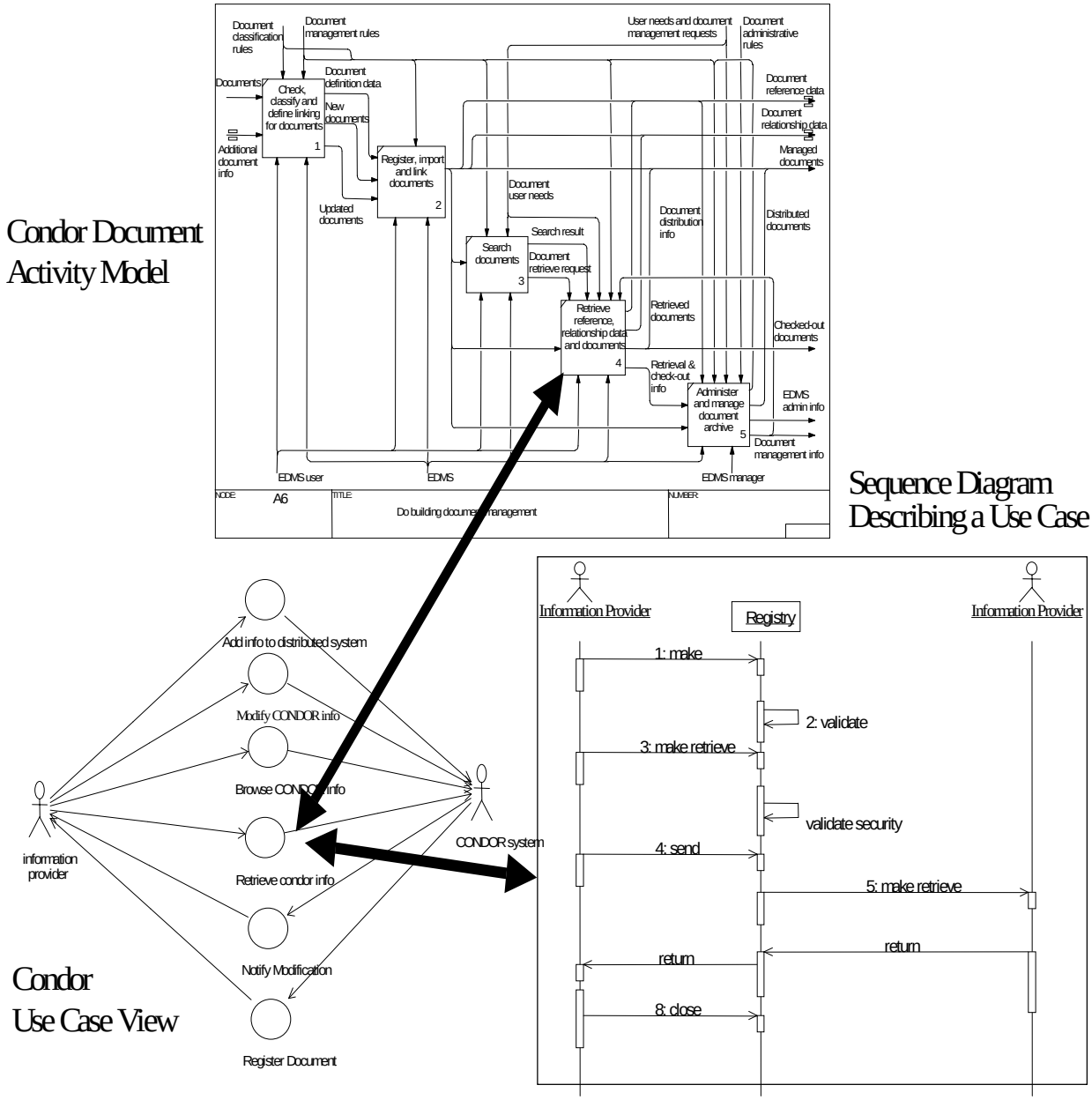

Figure 2. Understanding and Capturing the requirements of the Condor System.

4. THE UNDERLYING MODELING INFRASTRUCTURE SUPPORTING THE CONDOR SYSTEM

The CONDOR models have been developed using UML in the Rational Rose CASE tool. This language is rapidly being established as a de facto standard for object-oriented modeling, and is well supported by the Rational Rose CASE Tool. UML is developed primarily from two of the most popular modeling formalisms for object-oriented modeling, OMT [4] and Booch [5], and has recently been adopted as an international standard within the OMG

(Object Management Group). A set of information models have been developed within the Condor project as indicated in Figure 3. An overview of these models is given hereafter.

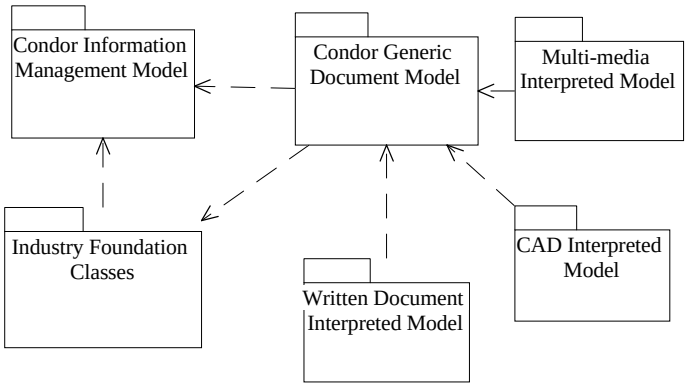

Figure 3. Condor Modeling Infrastructure

4.1. The Condor Information Management Model (CIMM)

This model describes how information is managed in the Condor system. This is based on the analysis of the business processes and document management practices of the construction end-users involved in the project. The CIMM involves the information providers that represent the various EDM systems used in the project; the registry that holds details about all the registered documentation (Information Elements) used in a project; and the adapter that enables a given EDM system to communicate with the registry to invoke various services.

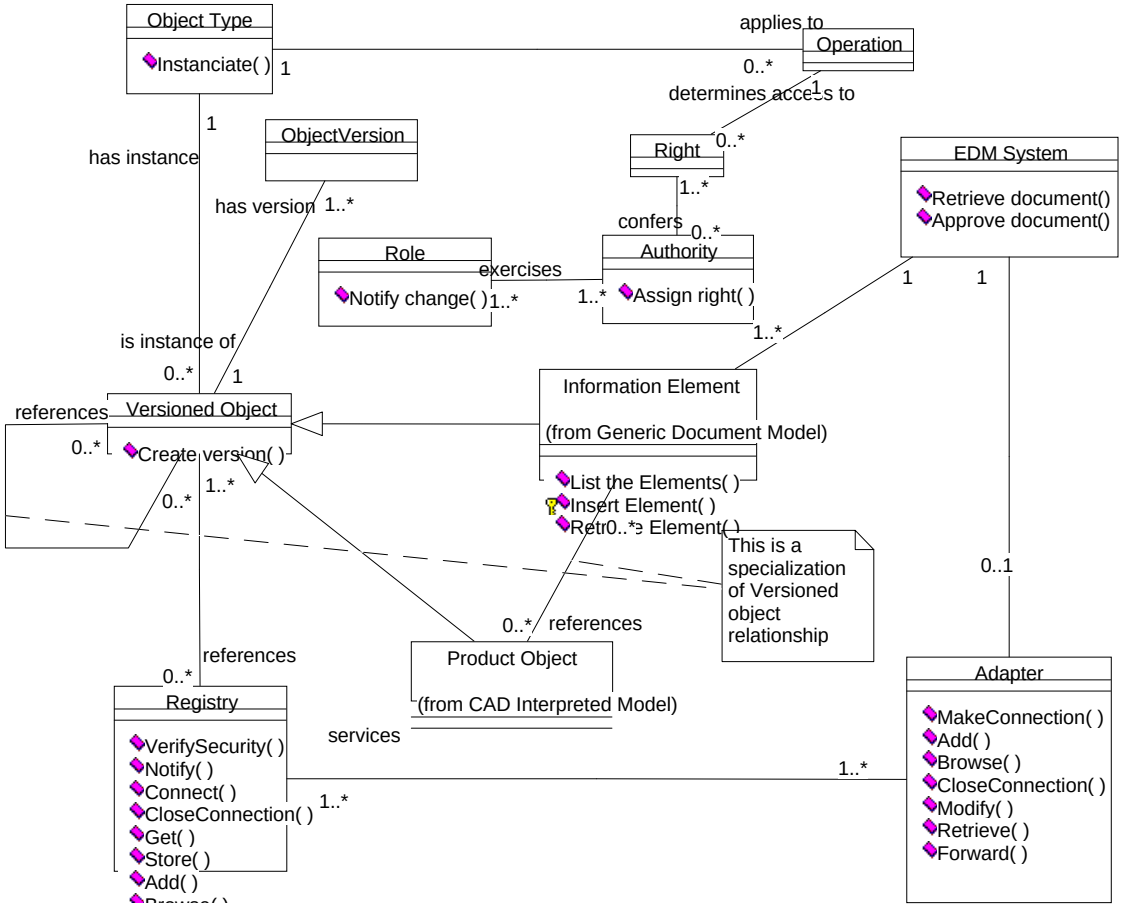

Figure 4. Condor Information Management Model.

Figure 4 shows the basis for the handling of information versioning and right over information in the CIMM. The concept of Role is introduced, in the sense that all actors participate in a project by means of one or more roles. Thus it is the concept of a role rather than an actor that falls within the scope of the CIMM. Through a role, an actor exercises authority over some parts of the project information, and each Authority is characterized by a number of responsibilities that relate to a particular object (Information Element). In order to discharge those responsibilities, the actor (through the role) needs to have certain rights to perform actions (or Operations) on the object in question. An important principle here is the use of operations on objects to define rights. This is in contrast to the conventional approach of assigning rights as: *Create*, *Read*, *Update* and *Delete*. In the Condor approach, the emphasis is on using real world concepts through the abstractions that may be represented in a true object-oriented model. For example, a project manager might have authority over a task in the project plan. In order to discharge the responsibilities associated with that authority, the project manager would need the rights to assign resources to the task, to move the start date of the task, etc. However, he or she might not have the right to delete the task, or change its duration. Naturally, this would depend on the specific situation, and the rights that the project manager would have over tasks might be different for different tasks. This suggests that rights must ultimately be defined at the instance level (e.g. over a particular task rather than over tasks in general).

In practice, however, there could be a huge number of combinations of rights to be assigned to roles and objects. For this reason, mechanisms are provided in the CIMM to allow default authorities to be defined over all objects of a given type. These authorities would apply in the absence of a specific authority for an instance. Similar mechanisms are being developed in relation to containment, whereby default authorities may be allocated in respect of an object by virtue of its being contained, or owned, by another object.

4.2. The Condor Generic Document Model

The Condor generic document model describes the logical structuring and semantic linking between the various forms of information used in the industry. These include written documents, drawings and multi-media objects, and are all defined as being documents. An information element might reference, or be referenced, by any number of other information elements. The semantics of any association between information elements is defined within the Information Element Relation class, as indicated in figure 5. An information element might also contain, or be part of, one or more information elements. For instance, a CAD layer might belong to more than one CAD drawing. The Information Aggregation class captures the semantic of this kind of aggregation between information elements. An information element is a versioned object (as indicated in figure 4) that is specialized into a Document, and a Meta Information Item (that constitutes a set of attributes to the document). An information element might reference one or more Product Object(s) (this could represent an IAI / Industry Foundation Class).

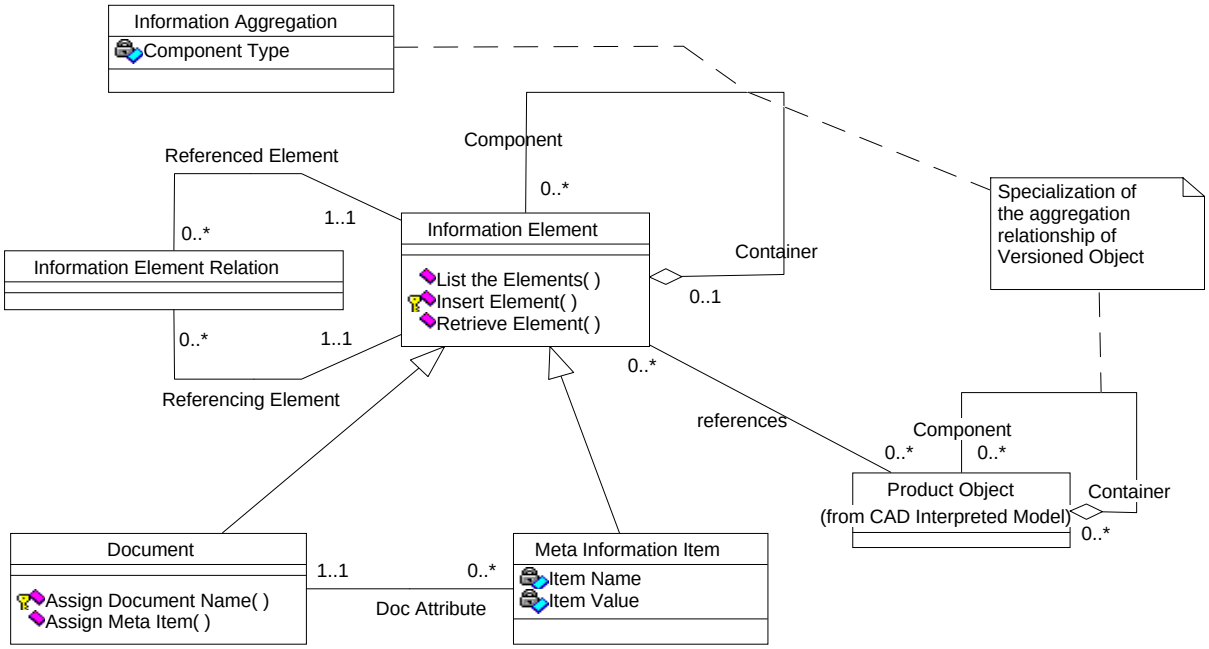

Figure 5. Condor Generic Document Model

4.3. The Condor Written Document Interpreted Model

The Condor Written Document Interpreted Model describes the logical structuring of a document. It is derived and specialized from the Condor Generic Document Model. A written document may contain one or more sections, as indicated in figure 6. Every section might have a title and a section number. Sections can take several forms, including paragraphs, table of contents, and formulas. One section may reference, or contain, other sections. The mechanism of inserting a new section to an existing one is achieved by invoking the inherited Insert Element method from the Information Element class. It is worth mentioning that this model supports the SGML syntax.

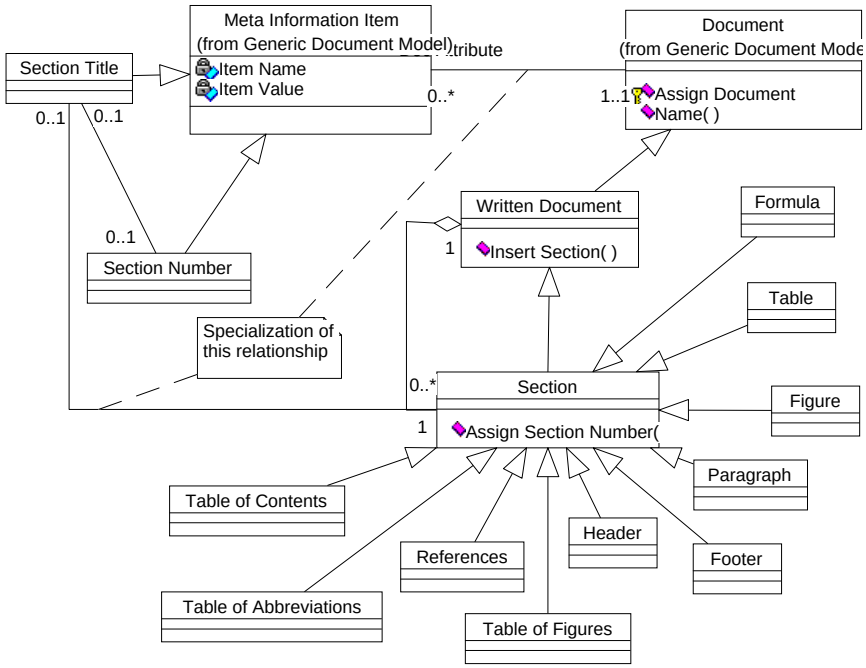

Figure 6. Condor Written Document Model

4.4. The Condor CAD Interpreted Model

The Condor CAD interpreted model provides an interpretation of the Condor generic model to describe the structuring of CAD drawings. The model has been developed from the ISO CAD Layering standard and the ISO STEP AP 202 application protocol. A CAD drawing is primarily described by means of the layers that constitute it (figure 7). It is worth mentioning that the use of layers facilitates the creation of task-specific documents, e.g. for individual activities on the construction site. Such a method would allow more flexible work task instructions than the traditionally pre-produced documents. A layer template can be provided by the responsible agent, and applied on demand to produce a drawing of the actual part of the building with just the information content needed to perform the specific activity [6]. This new approach to documentation also introduces new issues to be addressed, like the responsibility for the documents produced, and the procedures for revision. In addition, document search functions can use layers to identify documents or document sets concerning any of the properties covered by the layer structure. This may be useful in many situation, such as identifying all drawings that concern a certain building element or construction phase, or drawings that are produced by a certain actor [6].

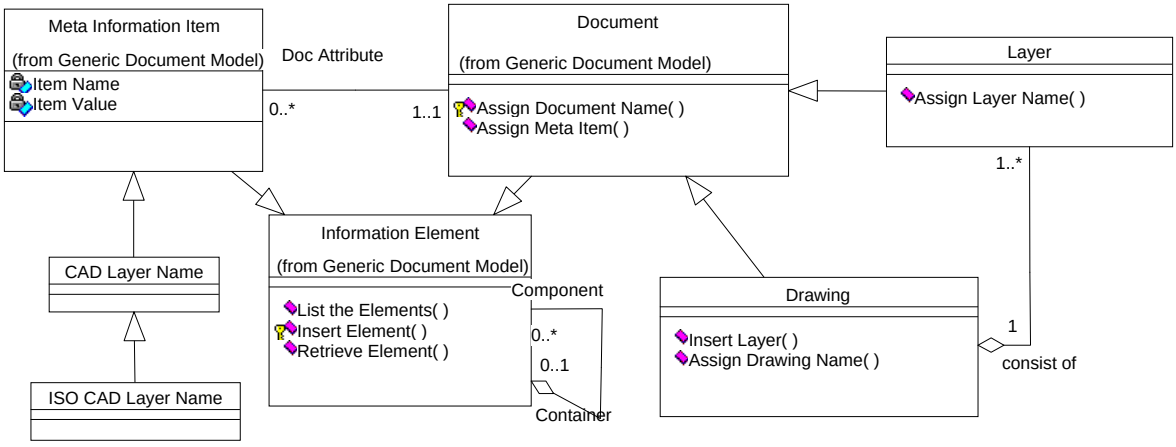

Figure 7. Condor CAD Interpreted Model

5. RE-ENGINEERING THE DOCUMENT MANAGEMENT PRACTICES

Business Process Re-engineering is an important element of the Condor project. In order to devise an effective strategy for the deployment of the Condor solution within the three end-users involved in the project, an approach based on surveys and data collection was considered. The latter made use of in depth interviews and mail questionnaires. The interviews were conducted with key players within each company involved in Condor. This approach, known as methodological triangulation technique, arises from the notion that qualitative and quantitative research methods are mutually complementary.

The questionnaire addresses the following topics:

- Personal information: general details of the company, department name and role within the company, position of the member of staff, etc.
- The extent of use of IT applications in the department and the overall company.
- Perceptions on company's environment, organizational culture, organizational structure, competition, resistance to change, role of IT, and company's policy in enabling change.
- Perceptions on Condor project

180 questionnaires have been distributed (60 to each company). The return process has not finished yet. However, we have drawn the following initial conclusions, based on the analysis of seventy responses to the questionnaire:

- 25%-35% of the personnel have marginal computer knowledge,
- 7%-12% of the personnel have formal computer training or strong interest in computers,
- 55%-65% of the personnel can write and process simple documents.

The responses to the questionnaire also revealed that there is a lack of awareness, a lack of communication between IT and business people, and a lack of co-operation between the different departments within a company.

The inter-organizational information sharing system suggested by Condor proves that organizational culture is a very important factor. We must be aware of possible risks of culture migration. The concept of culture, that can be defined as the particular way things are done in a company, operates at every level within an organization and can be a cause of frictions when two or more different cultures come into contact with one another.

These initial findings suggest that reengineering implementation is a very complex process that involves a variety of human, cultural and organizational factors. As one of the first pieces of empirical evidence based on the above study, this research emphasizes the importance of addressing BPR implementation within the broader context of organizational change, in a complex sociological and technical environment. The BPR research is still ongoing and aims at defining the appropriate process redesign strategy, within each company involved in the Condor project, to implement effectively the proposed solution.

6. CONCLUSION

This paper presented the European Esprit Condor project. An overview of the modeling infrastructure supporting the Condor system was given. The research team is presently implementing the extensions to the existing EDM systems in order enable information sharing and inter-working between these dissimilar systems. The ongoing developments are CORBA [3] compliants. The presented models are also being refined in the light of experience from implementation work.

This project is ongoing and supported by a user interest group, which involves representatives from a variety of non-construction industry companies. It is hoped that the latter will help to ensure that the results of the project are sufficiently generic to be transferred to industries other than construction, and to assist in the wider dissemination of results. It is expected that some of these companies will be interested in exploiting the Condor project results within their own organizations

7. ACKNOWLEDGEMENTS

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