AN INTEGRATED APPROACH FOR A MODEL BASED DOCUMENT PRODUCTION AND MANAGEMENT

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SUMMARY*: The primary aim of the research presented in this paper is to provide pragmatic solutions to the problems of integrity and consistency of document based information, describing a building throughout its life cycle. The research demonstrates the computer-aided generation of project documents via a construction project data model. The first research activity involved the development of a Construction Project Reference Model (CPRM) and a Document Reference Model, from which various Applied Document Type Models can be derived. The work concentrated on the French Full Specification Document: the CCTP (Cahier des Clauses Techniques Particulières), which is generated during the detail design stage. A generic Association Model was developed and used to index the CPRM's concepts to the CCTP's documentary elements supporting their description. Finally, the mechanisms enabling the generation of the project CCTP from the proposed structured reference CCTP are described. This research, which through the DOCCIME project involved a building research centre (CSTB), an engineering company (OTH) and a software house (O2 Technology), is ongoing (both in the Information Technology Institute of Salford University and CSTB) and primarily aims to develop and define a more generic platform supporting all forms of model-based information in the distributed and multimedia environment.*

KEYWORDS: Data Model, SGML, Computer Integrated Construction, Full Specification Document.

1. INTRODUCTION

Over the past three decades, the problems of document production and management have increased markedly along with the growing complexity of construction projects. Software vendors propose numerous tools to support the production and maintenance of documents at a basic level (drawing editors, word processors, table-sheet editors, etc.). Although such tools provide many helpful facilities (save, restore, edit, etc.), they rarely handle any semantic aspects of the information being processed, and therefore remain limited in their support to the end-user. However, high quality documents are required to ensure the success of construction project activities. The quality of documents may be measured by their consistency with the corresponding building regulations, by their consistency with the documents previously approved, and also by their consistency with the project itself through the absence of errors, omissions and redundancies. Once elaborated, these documents should fulfil the actor's information requirements with respect to the project description.

In recent years, a great deal of work has been carried out into the creation of central project databases which hold all information relating to a project according to a common product model. Such work includes COMBINE (Dubois et al., 1995), ATLAS (Bohms et al., 1994), MOB (MOB, 1994), RATAS (Bjoerk, 1994) and ICON (Aouad et al., 1994). However, due to a number of factors - technical, organisational and cultural - it is unlikely that this approach will be embraced in the short to medium term. There is, therefore, a need to investigate alternative approaches.

1 Previously CSTB.

In current practice, overall document management is often a personal issue, at best handled inside an office, but seldom on the project level. The state of the art research in this area can be roughly divided into the two following approaches:

- The integrated document management approach (Bjoerk, 1993), (Turk, 1994): documents are treated as black-boxes, and the aim of computer-support is to enable easy document retrieval using the reference information. This approach is starting to become best practice in the near future due to the proliferation of EDM (Electronic Document Management) systems.
- The model-based approach (Rezgui, 1994), (Debras, 1995): in this approach all the information, which traditionally has been contained in drawings and text documents, is contained in a single integrated data base from which information can be fetched using queries, and written documents can be produced almost automatically.

In between these two approaches, it is also worth mentioning the ISO layering standard proposal. The purpose of this ISO TC10/SC8/WG13 (ISO CAD layers standard) is to establish an agreed common basis for organising construction data in CAD systems (ISO, 1995).

The aim of the research presented in this paper, which lends itself to the model-based approach described above, is to provide pragmatic solutions to the problems of integrity and consistency of the information conveyed using document-based medium, throughout the whole construction project life cycle.

2. PROPOSED APPROACH

In order to propose an integrated approach for the management and computer-aided generation of construction project documents, the following key research questions were addressed:

1. How to propose a pragmatic approach leading to computer-aided generation of project documents, through a formal and explicit description of a building?
2. How to propose an easy and structured access to the information contained within project documentation and regulations, to any actor involved in the construction project process?

In order to deal with the first point, we propose to address the contents of the documents through a conceptual modelling approach. This allows documents to be structured in a logical way regardless of any programming languages, proprietary softwares or hardware platforms. This kind of approach lends itself to the use of standard formats (e.g. SGML), as these will survive the rapid development of IT. This modelling work will identify the various components of documents and their inter-relationships. Specific documentary models might then be derived for selected types of documents: bills of quantities, full specifications, etc. Using such an approach can be seen as a form of business process reengineering where the document format is radically altered using the opportunities offered by new hardware and software methodologies, for example, the Internet, CD-ROM and Hypermedia. The first key research question is addressed as follows:

1. The development of a Construction Project Reference Model (CPRM): the CPRM has been developed using NIAM2 (Nijssen, 1989) and EXPRESS (EXPRESS, 1992). The CPRM was notably used for the DOCCIME project (Debras et al., 1994) funded by Plan Construction et Architecture (French organisation of the Ministry of Equipment). The CPRM provides a description of a building and its related components, based on a systemic approach. It is considered as the hub of the proposed methodology through which document integration is achieved.
2. The development of a Document Reference Model, from which will be derived several types of Applied Document Type Models. The work concentrated on the French Full Specification Document: CCTP.
3. The development of an Association Model: the connection between the building description and the proposed documentary models is achieved by indexing the CPRM concepts to the documentary elements

[2] NIAM is an entity-relationship modelling language used to describe the proposed models. It was chosen because of the availability of tools implementing the NIAM modelling methodology. In addition, NIAM was, at DOCCIME's inception, widely used among the AEC research community.

supporting their description. This indexing is implemented via an Association model whose instances drive the computer-aided production of project documents.

4. The specification of the approach along with the mechanisms allowing the generation of a construction project CCTP from a proposed structured reference CCTP.

In order to deal with the second point, we propose to generate and implement hypertext references which enable navigation from one documentary item to another (internal or external to the document) of either a project document or a construction standard. The proposed overall approach was thus structured into the six following main stages as indicated Fig. 1.

Stage 1: Analysis

This stage consists of analysing, on one hand the current practices in document management and production, and on another the existing project document types. In particular, this analysis should be extended to describe how each document type relates to:

- standards, regulations, manufactured product information and other project documents,
- the building and its different parts,
- the activities of the design, construction and maintenance processes.

Stage 2: Conceptualisation

This stage can be decomposed into three main tasks:

- propose a documentary reference model that will be specialised according to chosen document types (BoQ, Full Specification, etc.),
- propose a Construction Project Reference Model,
- propose an Association Model which indexes building concepts to documentary items.

Stage 3: Implementation

This stage is applicable to both the documentary and building domains and consists of:

- generating the SGML Document Type Definition of the chosen document types,
- generating the physical schemas of both the CPRM and the Association Model.

Stage 4: Instantiation

The instantiation stage can be divided into three main tasks:

- restructure the chosen project CCTPs to fit the proposed Applied Documentary Models,
- mark up the proposed documents,
- populate the CPRM according to a chosen construction project.

Stage 5: Elaborate the knowledge base

The Association model will be populated by indexing the Building concepts to the Applied Document elements supporting their description. Each document type will have its own correspondent knowledge base.

Stage 6: Demonstrate the whole approach

The demonstration will be based on a real construction project.

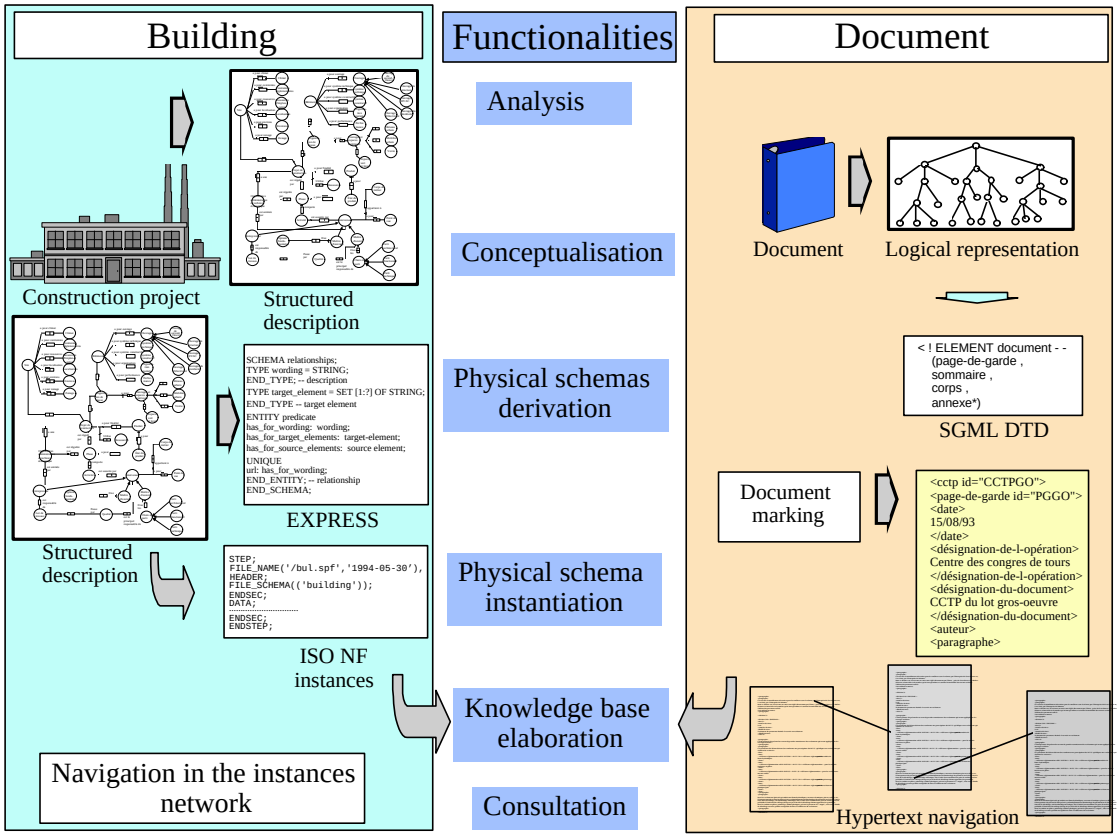

Fig.1: Model based document production approach

3. DOCUMENT ANALYSIS

A document is, in some respects, a Product according to the STEP (Cutting-Decelle, 1994) definition. It is a transitional and changing object defined within a precise stage of the Project Life Cycle (Fig. 2). In general, a document is related to other elaborated documents of the Project Documentary Database. A Document has one or many authors. It is described by general attributes such as a Code, an Index, a Designation, a date of creation and its Author(s). A list of updated versions also keeps a record of any amendments made to the document. A document may have an associated indexing system. Some documents are submitted for approval according to a defined set of examiners representing various technical and legal domains. Each examiner issues a statement which enables the document to be approved, refused or approved with reservation (Fig. 4).

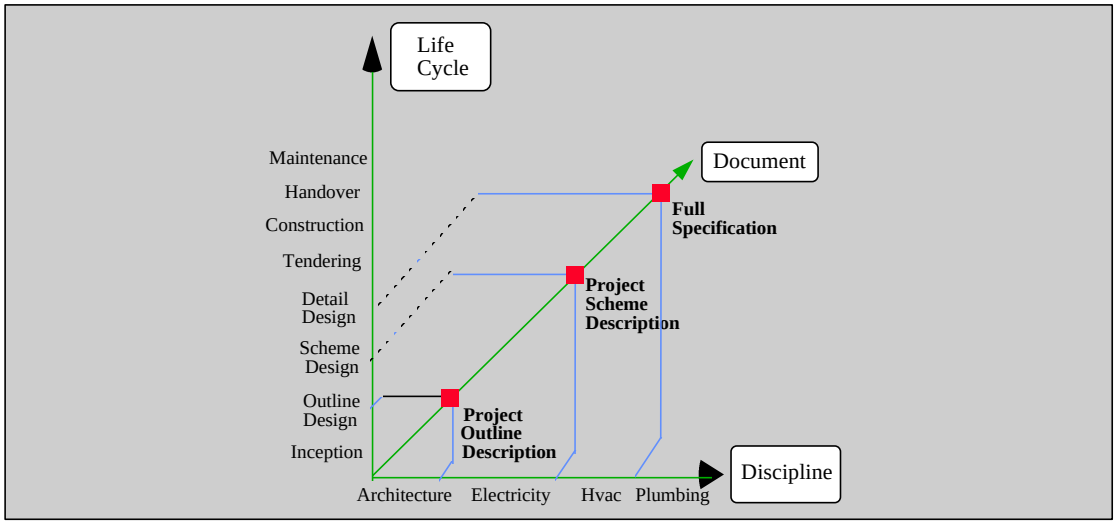

Fig. 2: Document genesis

Once described, specific project document types need to be analysed more deeply. Among the numerous documents generated within a construction project design stage, the CCTP (French full specification document) seems to be the most important for the following reasons:

- it involves a significant number of specialists from various domains,
- it is large in terms of text volume, number of documents and number of links between documents,
- it has particular relevance as a contractual document.

The CCTPs also provide precise answers to questions from the various project actors: the architect is concerned with the global control of the project in accordance with the brief and the detailed design, the project's contractors use them as a basis for implementing construction works, the technical authorities can use the CCTP's specifications to approve the project and check the safety of the works undertaken, etc. An analysis of CCTPs, written by the same company but addressing several different projects, reveals similarities in both their structural level and the nature of their semantic content. A common structure can be extracted from this analysis (Rezgui, 1994). It consists of documentary divisions of different levels, each of which is dedicated to a precise theme. We distinguish four main themes :

- generalities common to all work packages ;
- technical instructions and specifications ;
- description of the works undertaken within the work package ;
- interfaces between work packages.

This common structure is then used as a basis for developing the CCTP Applied Documentary Model. Assuming the applicability of the proposed approach to any project document type, we have limited the research scope to the CCTP case.

4. CONCEPTUALISATION

The conceptualisation activity was undertaken for both the document and building domains, as described below.

4.1. Document modelling

The Documentary Reference Model (Fig. 4) is an analytical representation of the numerous documentary concepts and attributes describing both the genesis of a document, from its creation to its final version, and its contents. This model can therefore be divided into a Documentary Genesis Reference Model and a Documentary Contents Reference Model (Fig. 3). The latter is specialised into various Documentary Contents Applied Models in accordance with existing document types: Briefs, Full Specifications, Bills of Quantities, etc.

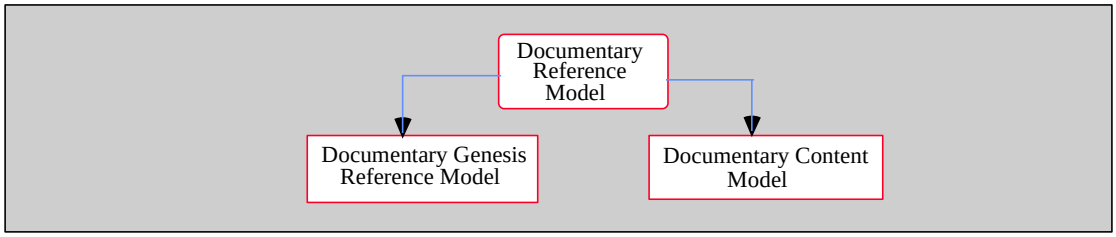

Fig. 3: Documentary Reference Model Decomposition

The content of a written document consists of a cover page, a summary, a body and some appendices. The cover page usually holds the document's general attributes (title, authors, version...). The body of the document consists of a structure giving rise to divisions defined by their hierarchical level. The divisions have a title defined by a number as well as a label; their content can be modelled by similar smaller grain size models made up of paragraphs and lower level divisions. A paragraph is composed simply of plain text and/or lists of items. Paragraphs and items may also include floating elements such as tables, figures, formulae, and references, which may be internal to the document or external. External references may concern documentary elements of the project documentary database, or elements of other databases such as the Building Regulations.

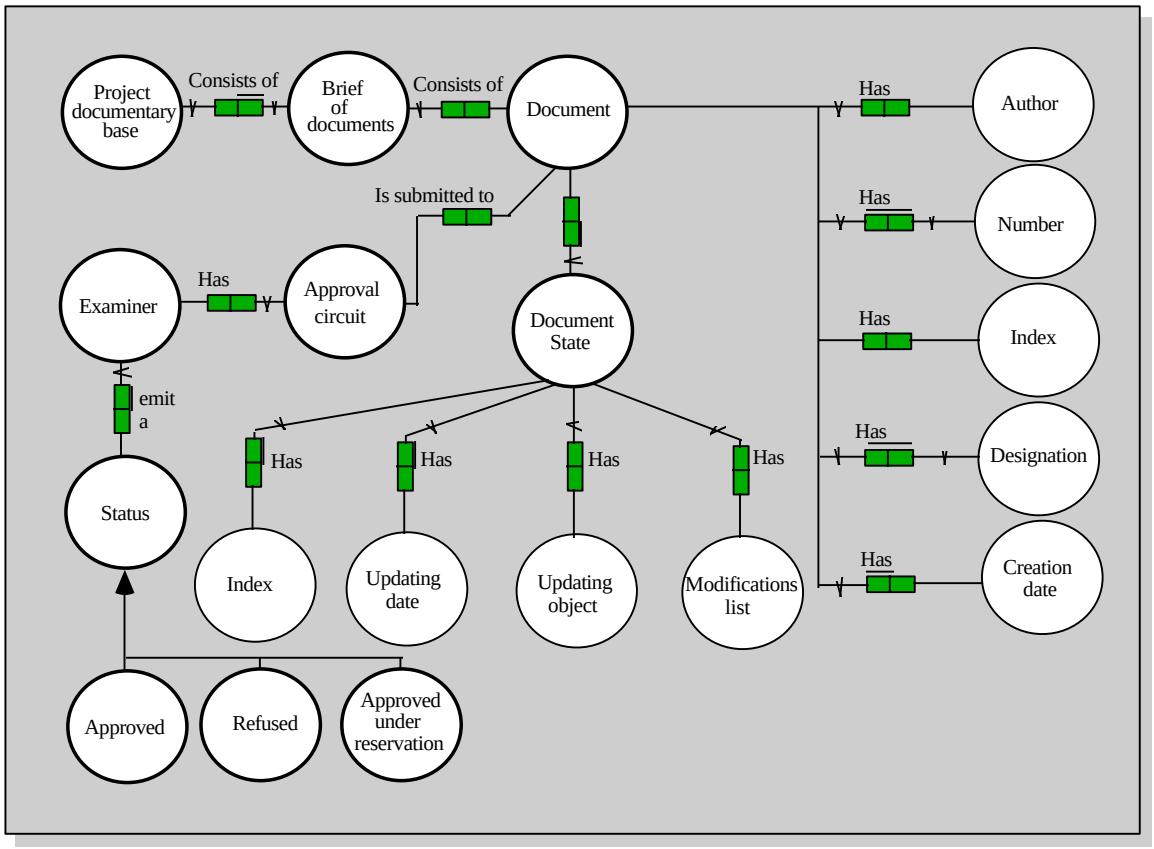

Fig. 4: A partial representation of the Document Reference Model

4.2. Building modelling

The Construction Project Reference Model (CPRM) developed at the CSTB (Rezgui, 1994) is used as a basis for the generation of project documents. It consists of a neutral data model through which the project's actors communicate and exchange information. From this model the Applied Project Data Models can be derived, by making use of specialisation and inheritance mechanisms. The CPRM is composed of generic entities of relevance to the construction project. It is structured into several levels of abstraction in order to describe the inter-relations between entities, and how entities constitute the various building systems. This modelling work is based on a top-down approach guided by the notion of view. The CPRM is structured into three main branches : the site, the master plan organisation and the technical and administrative organisation. The master plan organisation comprisesboth buildings and external spaces.

The CPRM's highest level of abstraction integrates product data with activity data and defines the appropriate generic concepts for describing a construction project's genesis (Fig. 5). Similarily, it is worth mentioning the IRMA project (Luiten et al., 1993) which defined generally applicable relationships between products, activities, resources and participants in a building project.

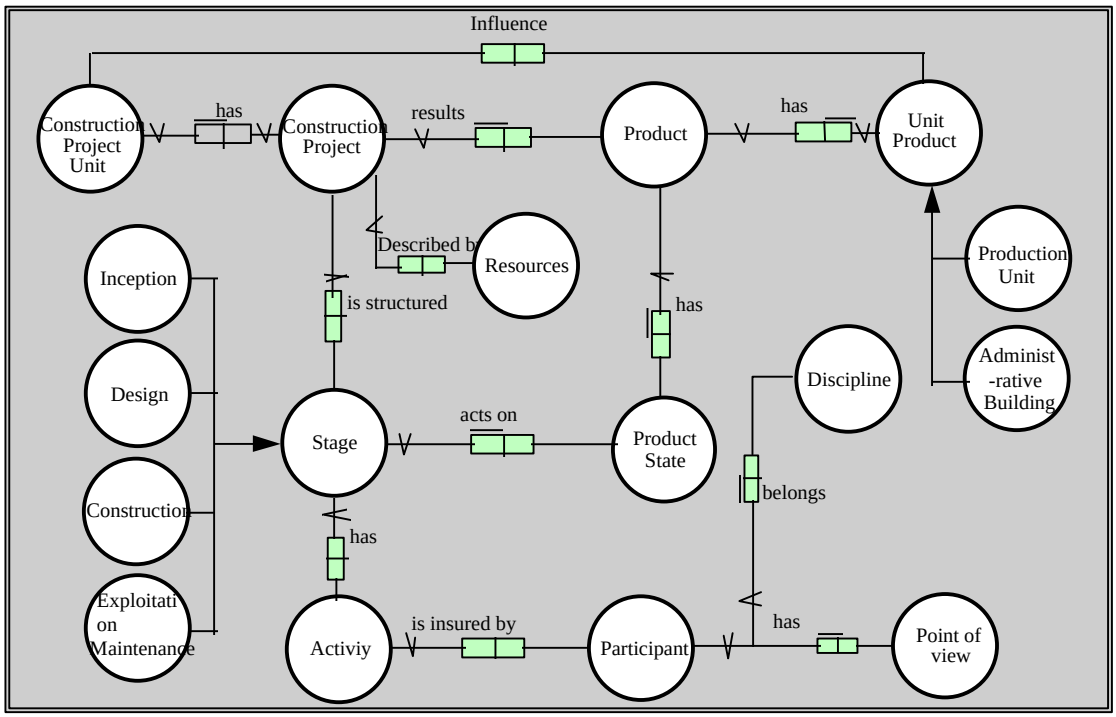

Fig. 5: The CPRM's main concepts

The Building is described according to five complementary systems: the structural system, the work system, the space system, the technical system and the separation system (Fig. 6). In general, the building entities describing the CCTPs belong to the work system, although some entities are provided by other building systems.

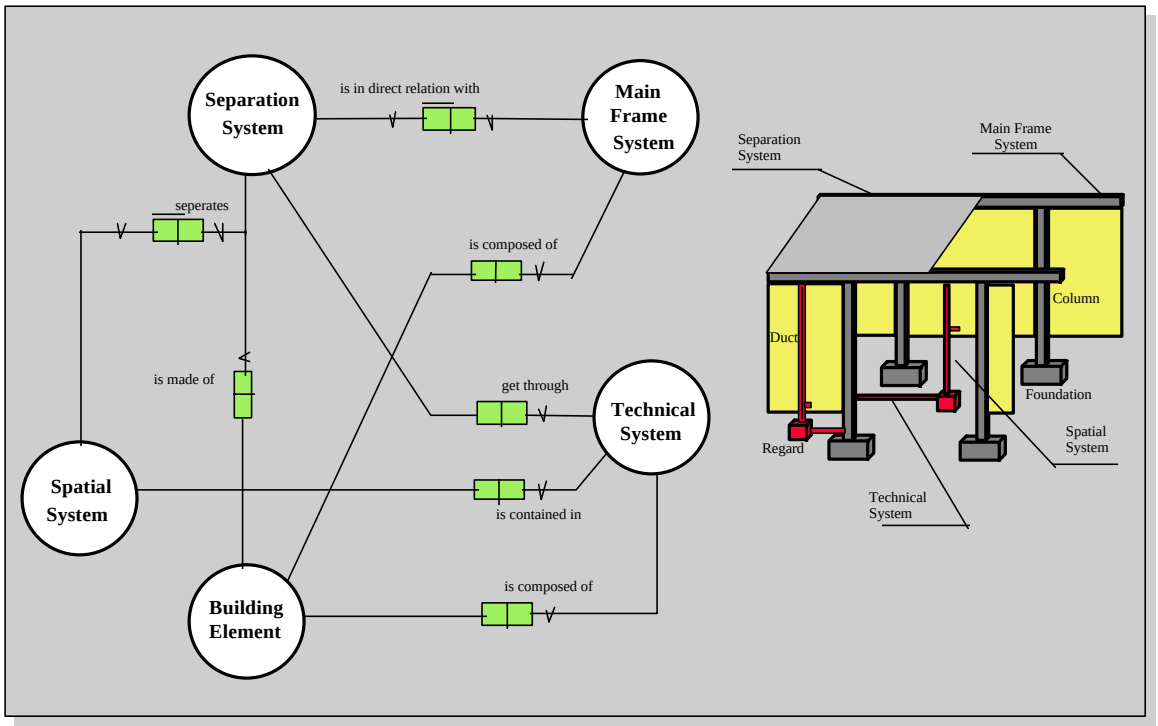

Fig. 6: Building systems

An EXPRESS representation of the CPRM is then derived.

Numerous building data models have already been developed. Moreover Building Application Protocols are being defined within the frame of the STEP project. The CPRM briefly presented here takes account of and evolves according to all these ongoing works.

5. IMPLEMENTATION

Physical representations of the above described documentary and building models have been derived according to various standard formats such as EXPRESS3 schema (STEP), SGML Document Type Definitions, "O2 Technology"4 and relational databases tables (Fig. 7).

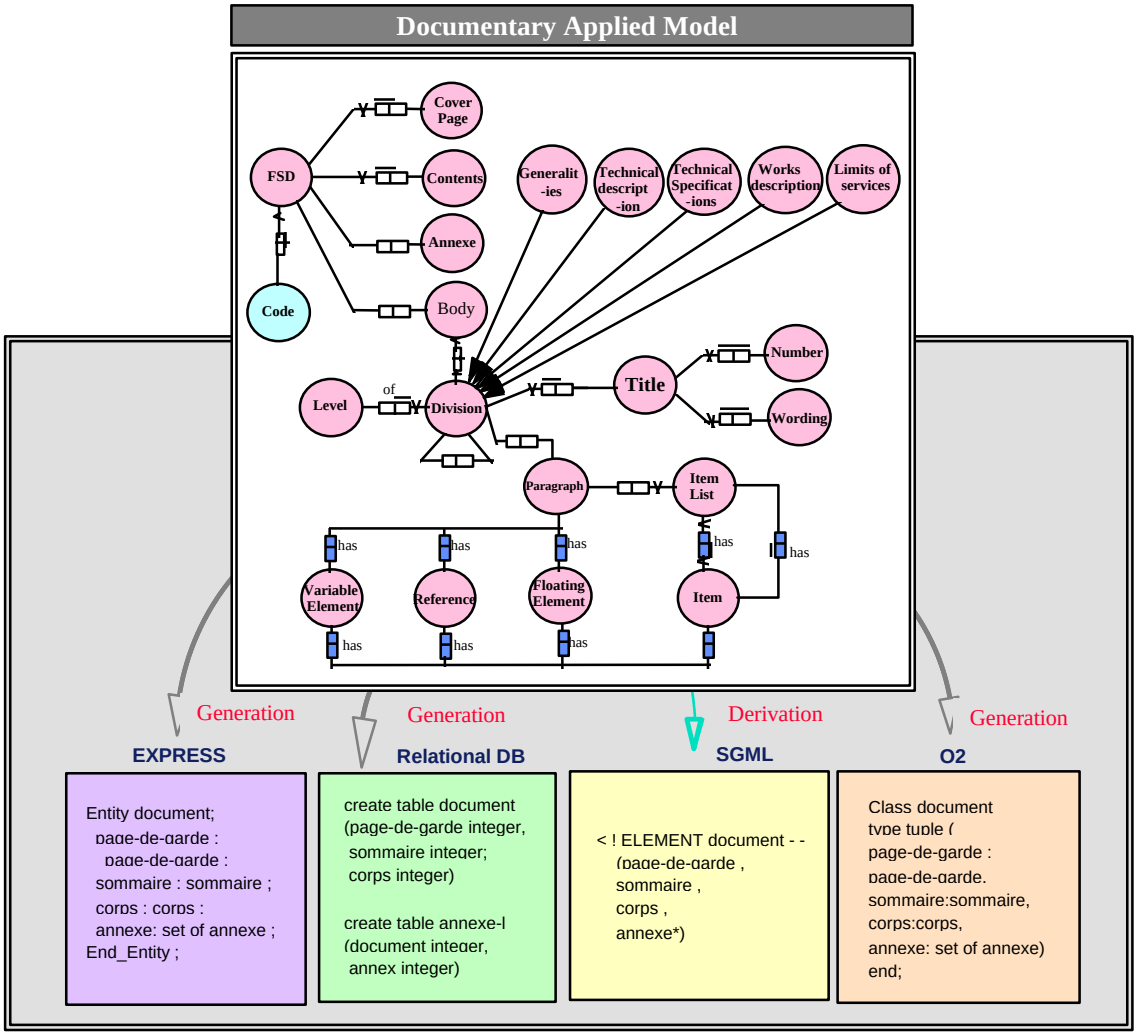

Fig. 7: Documentary models implementation

The SGML DTD of the CCTP document, which was manually generated, is described in annex A.

[3] EXPRESS schema was generated by means of the XP-XPRESS-G tool of the XPDI platform developed at CSTB. The DOCCIME project treated EXPRESS as a physical schema from which various standards were derived.

[4] O2 Technology is an object-oriented database developed and commercialised by O2 Technology.

6. INSTANTIATION

The instantiation work was carried out simultaneously for the CPRM and a chosen set of CCTPs describing four construction work packages: Main frame, Carpentry, Plumbing and Waterproofing, in accordance with a sample project provided by OTH. This activity was comprised:

- Restructuring, in accordance with the proposed Applied Document Type Models, and mark-up of the four chosen CCTPs.
- Instantiation of the CPRM concepts, particularly the ones whose description is supported by the four selected CCTPs. The instantiation of the CPRM was undertaken on the XPDI platform, developed at CSTB. An extract of the resulting ISO Neutral File is presented below.

```
STEP;
HEADER;
FILE_NAME('/home/debras/doccime/demo/batiment.spf','1994-05-30 T14:56:56',
('batiment'),(' XIG '),'STEP VERSION 2.0 e',,,'APPROVED BY XPDI ');
FILE_SCHEMA(('batiment'));
ENDSEC;
DATA;
#0=construction_project('cd1','fifty_flats_project',(' semi_detached_fifty_flats_in_Par
is'),'150MF','45MF','5MF','C',#76,(#75),(#77),#3,#2,#4);
#1=building('bat1','building_the_eucalyptus',($),'1500,00m2','1350,50m2',#2,#27,#28,(#
31,#30,#32,#33),(#72),$,(#79,#80,#81));
#2=master_plan_organisation((#0),(#1),(#26));
#3=site('NORMAL','1','1','1',$,'7','0.5','1.15','2');
#4=technical_and_administrative_organisatiom();
.............
#35=infrastructure(#28,(#37),(#40),'CF-2H');
#36=superstructure($,(),(),'CF-1H');
#37=infrastructure_unit((#5,#11,#7,#6,#9,#10),(#53,#17,#15,#54,#56,#57),(#58),(),());
#38=superstructure_unit((#60,#61,#62,#63,#64),(),());
.................
ENDSEC;
ENDSTEP;
```

This instantiation work was mainly undertaken by OTH who was deeply interested by the assessment of the benefits that would be gained from using the techniques and tools developed in relation to the case study.

7. ELABORATE THE KNOWLEDGE BASE

This chapter presents the approach and the different stages enabling the generation of the CCTPs of a construction project. Particular emphasis is placed on the structure of a knowledge base which allows building data model concepts to be associated with documentary items.

7.1. Presentation of the approach

The reference CCTP associated with each work package is an assembly of documentary items (divisions, paragraphs), where only a subset is relevant to a given project CCTP. In fact, amongst the documentary items making up the proposed structured reference CCTP, many support the description of works and potential construction processes with respect to a given work package. The existence of these documentary items is thus constrained by their presence or use in the project. Furthermore, CCTPs may contain internal links (hold within the document and referencing one item to a set of other items) or external ones (linking a document's items to external ones belonging to either project's documents or Building Standards). Consequently, when the project CCTP is produced, any internal or external link to deleted documentary items should be suppressed. The reference CCTP also contains variable elements (region, site) which need to be specifically detailed for a given construction project.

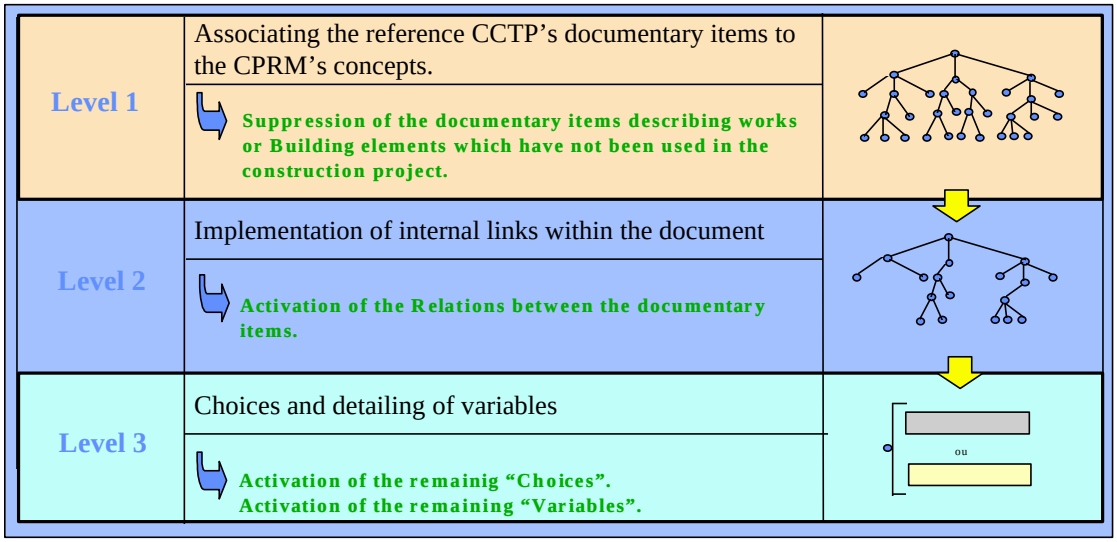

Fig. 8: The proposed approach for document generation

We now propose the procedure through which a reference CCTP becomes a project CCTP, with respect to a precise construction project (Fig. 8). At the initial stage, all the reference CCTP's items are selected. Their existence is then evaluated according to an elaborated knowledge base. To demonstrate the approach four strongly-related work packages have been selected: main structure, waterproofing, plumbing and external carpentry. The proposed approach comprises three main stages, each of which corresponds to an increasingly discriminatory level of document analysis.

7.2. Associating the referencecctp's documentary itemsto the cprm's concepts

A project description relating to the site, to the use of certain materials or processes and to the presence of certain types of works enables the discarding of a set of documentary elements irrelevant to the project. The fact is that some documentary divisions composing the CCTP, such as 'Technical instructions and specifications', are not directly linked to a precise type of work but necessitate a global evaluation of the project works. For example, the absence of a pre-stressed concrete beam constitutes a necessary condition for the deletion of documentary elements dealing with pre-stressed concrete. However, it does not constitute a sufficient condition as there may be other pre-stressed concrete elements such as columns and slabs. This deletion is possible only if the project includes no pre-stressed concrete work. Globally, this macroscopic description of the document concerns diverse aspects of the project as shown by the examples below.

Waterproofing section

- *the project includes an independent waterproof coating system;*
- *the project includes an adhesive waterproof coating system;*
- *the project includes a semi-independent waterproof coating system:*
- *the process of projected polyurethane foam is used, etc.*

Shell section

- *the foundation ground requires consolidation;*
- *the infrastructure includes a deep foundation system;*
- *the infrastructure includes a semi-deep foundation system;*
- *the infrastructure includes a superficial foundation system;*
- *the pre-stressed concrete is used in the project;*
- *etc.*

Plumbing section

- *the project takes into account the standards and decrees concerning the physically handicapped;*
- *the project uses a water superpressure system;*
- *the project includes parkland with automatic reticulation;*
- *etc.*

This description may be formalised in the form of questions evaluated directly by the user, or by the implementation of links between the reference CCTP's elements and the CPRM's concepts. This association is implemented via the instantiation of a dedicated concept labelled predicate which is described below under the EXPRESS formalism.

```
SCHEMA predicate;

TYPE wording = STRING;

END_TYPE; -- wording

TYPE building-concept = STRING;

END_TYPE; -- building-concepts;

TYPE target_element = STRING;

END_TYPE -- target element

ENTITY predicate

has_for_wording:  wording;

has_for_building concepts:  SET [1:?] OF building-concept;

has_for_target_elements:  SET [1:?] OF target-element;

UNIQUE

url: has_for_wording;

END_ENTITY; -- building-concept

END_SCHEMA
```

The example below carries four instances of the predicate entity associating the "Description of works" division of the main structure and the CPRM concepts.

```
predicate
      wording "Earthworks"
      building-concepts ("earthworks")
      target-elements ("DESGO2")
      end-of-object
predicate
      wording "Stripping (elimination of the superficial layer of ground before works)"
      building-concepts ("stripping")
      target-elements ("DESGO2b")
      end-of-object
```

```
predicate
      wording "Large scale excavations"
      building-concepts ("large_scale_excavations")
      target-elements ("DESGO2c")
      end-of-object
```

7.3. Implementation of internal links within the document

A series of pre-defined dependence relationships is implemented to take into account the resultant propagation of the deletion of documentary items carried out in stage 1. The dependence relationships originate from items in the 'Description of works' division and point towards items in the 'Technical instructions and specifications' and 'Interfaces between work packages' divisions. The EXPRESS schema which describes these dependent relationships is presented below.

```
SCHEMA relationships;
TYPE wording = STRING;
END_TYPE; -- description
TYPE target_element = SET [1:?] OF STRING;
END_TYPE -- target element
ENTITY predicate
has_for_wording:  wording;
has_for_target_elements:  target-element;
has_for_source_elements:  source element;
UNIQUE
url: has_for_wording;
END_ENTITY; -- relationship
END_SCHEMA;
```

Examples:

Shell section

The division relating to 'Deep foundations ', a sub-division of the'Description of works' division , is linked to the following documentary items:

- *'Works for capping the deep foundations' division;*
- *'Technical specifications regarding deep foundations' division;*
- *reference to the building standard relating to deep foundations.*

Plumbing section

The division relating to 'Description of water superpressure', sub-division of the 'Description of works' division, is linked to the following documentary items:

- *'Technical specifications regarding superpressure devices division;*
- *'Description of the superpressure technical premises' division.*

The information base relating to the dependent links between documentary items is expressed in the form of "relationship" object instances.

```
relationship
      wording "Filling works, consolidation of quarries."
      source-elements ("DESGO3a")
      target-elements ("SPEGO2b")
      end-of-object
relationship
      wording "Earthworks consolidation by injection."
      source-elements ("DESGO3a")
      target-elements ("SPEGO2b")
      end-of-object
relationship
      wording "Superficial foundations (pad)."
      source-elements ("DESGO3h" "DESGO2gp1" "DESGO31nI1"]
      target-elements ("DOCREFI214" "SPEGO2p")
      end-of-object
relationship
      wording "Superficial foundations (radier)."
      source-elements ("DESGO3i" "DESGO31hP1" "DESGO31nI1"]
      target-elements ("DOCREFI214" "SPEGO2u" "SPEGO2zab1I2" "SPEGO2zab3" "SPEGO2zab5I1"
      "SPEGO2zab5P1" "SPEGO2n"]
      end-of-object
```

7.4. Choices and detailing of variables

A new procedure for the description of the project enables a more discriminating elimination of documentary items which deal particularly with the choice of procedures.

Examples :

Waterproofing section

Multiple choice associated with the type of thermal insulation used:

- *choice 1: "Fibreglass insulation permeated with formo-phenolic resin"*
- *choice 2: "Thermal insulation with high-density fiberglass panel"*

The information base relating to choices is expressed as instances of the "choice" entity. At this stage, the structure of the CCTP document is globally fixed and is consistent.

```
choice
      containing "TTI1"
      wording "Thermal insulation of inaccessible terraced roofing with gravel protection by:"
      questions
```

```
            wording "composite panel"
            'identifying "TTI1b1"
            wording "rigid polyurethane foam panel"
            'identifying "TTI1b2"
end-of-object

choice
      containing "TTI3"
      wording "Thermal insulation of inaccessible terraced roofing with self-protected
      waterproofing by:"
      questions
            wording "composite panel"
            identifying "TTI3b1"
            wording "perlite insulation panel"
            identifying "TTI3b2"
end-of-object
```

The last procedure consists of detailing the variable parts contained in the remaining documentary items. The information base relating to these parts is expressed as instances of the variable entity.

```
variable
      identifying "HYPGO6VV2"
      containing "HYPGO5"
      wording " Category of a site with regard to wind."
      building-entity ("site")
      building-attribute ("class_site_wind")
      possible-values ("Normal", Exposed")
      Value-by-default- ("Normal")
      question "Enter the site class relating to wind."
end-of-object

variable
      identifying "HYPGO6V2"
      containing "HYPGO7"
      wording " Seismic group."
      building-entity ("site")
      building-attribute ("seismic group")
      possible-values (1,2,3)
      Value-by-default- (1)
```

```
      question "Enter the seismic group."

end-of-object
```

7.5. Document validation

Having reached the final stage, the project CCTP might eventually be slightly amended or completed on a textual level which does not challenge the structure of the document. The document is then converted via the application of a style sheet to the documentary model in a format compatible with a word processing tool (RTF for Word for example). The approach presented in this paper is based on the CCTP document. It can, however, be generalised (as indicated in figure 1) andapplied to any other written documents arising from a construction project.

8. Demonstrate the whole approach

The prototype implementing the approach presented in this paper consists of an extension of the DOCSET[YR1]5 tool (Debras, 1994). As stated before, every document constitutes an instance of the document class. This class identifies a precise type of document. The instances of a document are themselves connected to a documentary base as illustrated inthe DOCSET management panel

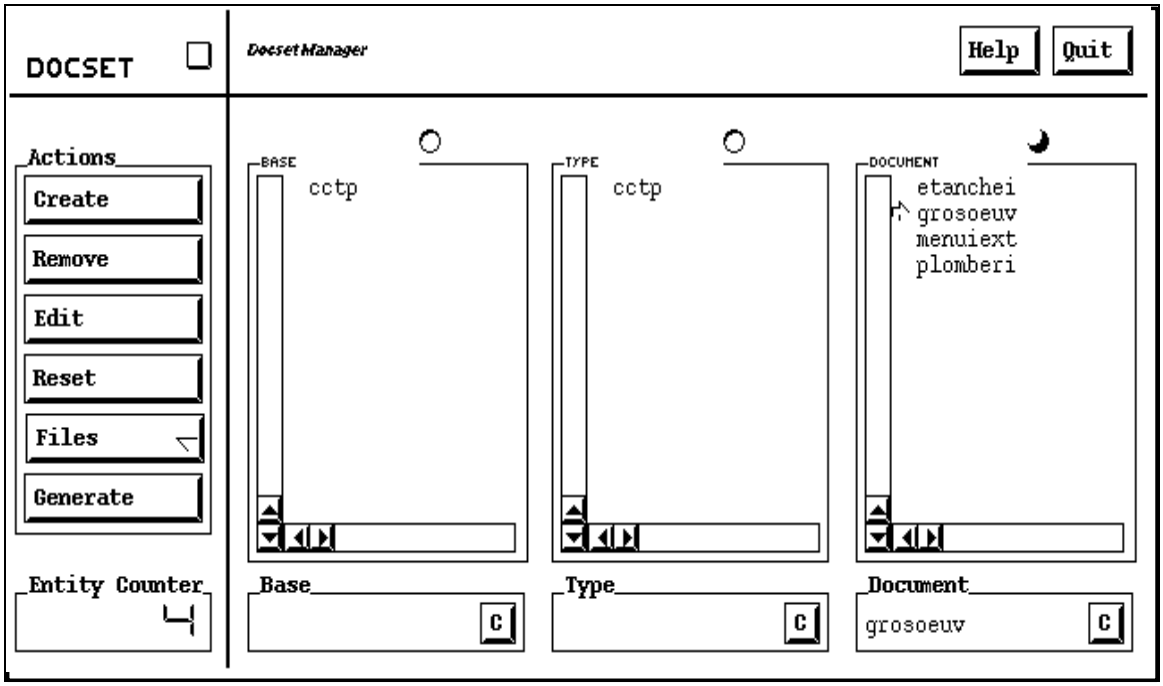

Fig. 9: The DOCSET Management Panel

Firstly, DOCSET enables the editing of a reference document summary in a tree form (DOCSET browser panel, Fig. 10). This function enables an exhaustive global viewing of the contents as well as the logical structure of the document.

[5] DOCSET is a software workbench available on UNIX machines (X WINDOW System) and 486 PCs. It is built upon the ILOG. SA environment comprising theAIDA and MASAI packages

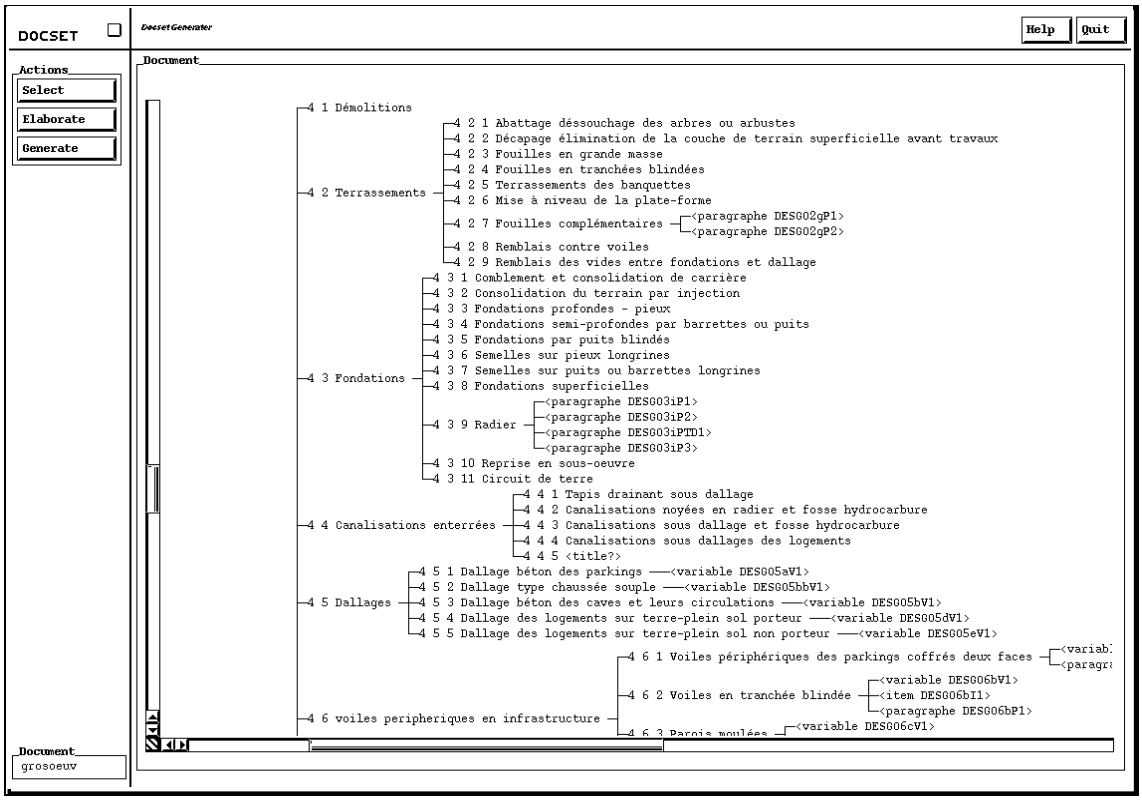

Fig. 10: The DOCSET Browser Panel

The user then has the possibility of consulting or developing the information base of the active document. This information base is structured according to four distinct levels, each of which corresponding to a level of detail and discrimination in the analysis of the document. The corresponding panel, when the information base is established, is called Elaborater(DOCSET Elaborater panel, Fig. 11).

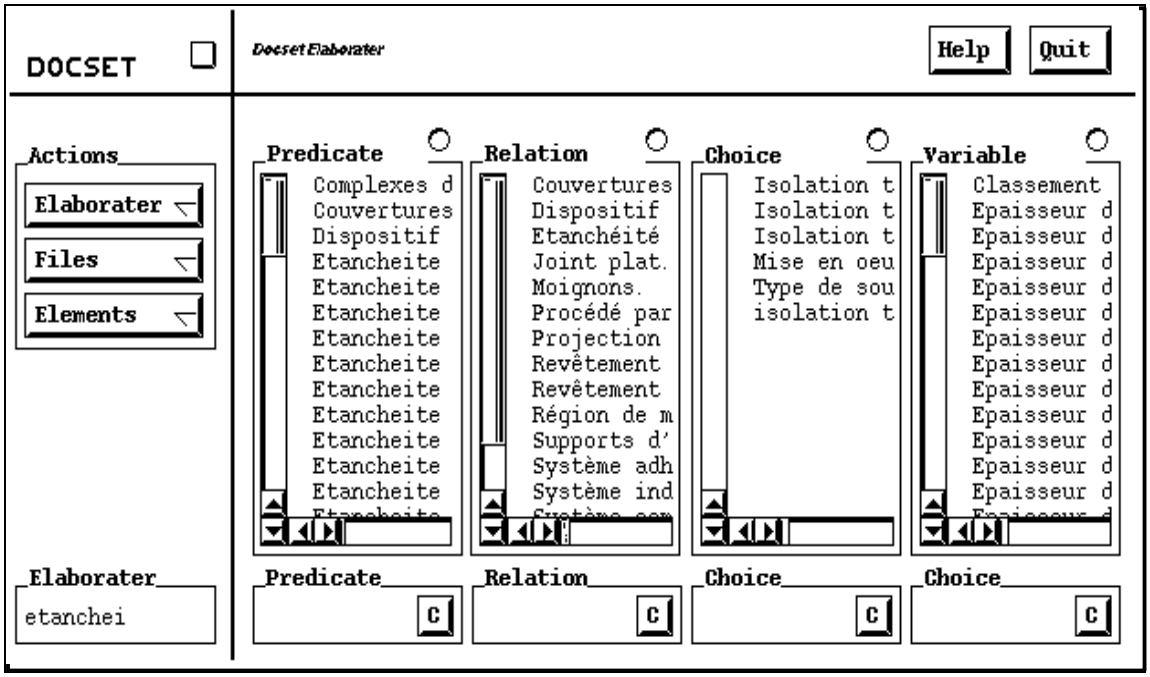

Fig. 11: The DOCSET Elaborater Panel

Two possible scenarios have been proposed for the generation of the project CCTP using the information base. The first scenario is limited to the use of the advanced browsing functionalities provided by DOCSET. The user, through his knowledge of the project, has overall control over the document. He can, therefore, delete documentary elements he judges to be inconsistent with the real project's description. Furthermore, there is no semantic control of the process leading to the creation of the project document and the user is responsible for the end result. The second scenario consists of an automatic generation of the project document via the instances of a building data model, in our case the CPRM. The principle is simple: it consists of verifying for each predicate whether the building concept supporting the description of a documentary item of the 'Description of Works' division has been instantiated. If the verification is positive, the documentary item is preserved, otherwise the item together with all its leads must be deleted. Once the predicates are evaluated, the Elaborater enables relationships to be activated which control the propagation of deletions made via the predicates. The relationships originate from the 'Description of Works' chapter identified by the "Source IDs" and point towards the other document's chapters identifiedby the "Target IDs".

The Predicate evaluation can be done either manually (by activating the concerned predicates or by discarding nodes of the document tree) or automatically based on the CPRM instances. The state of deletion is translated by a crossed out representation of theconcerned node (Fig. 12).

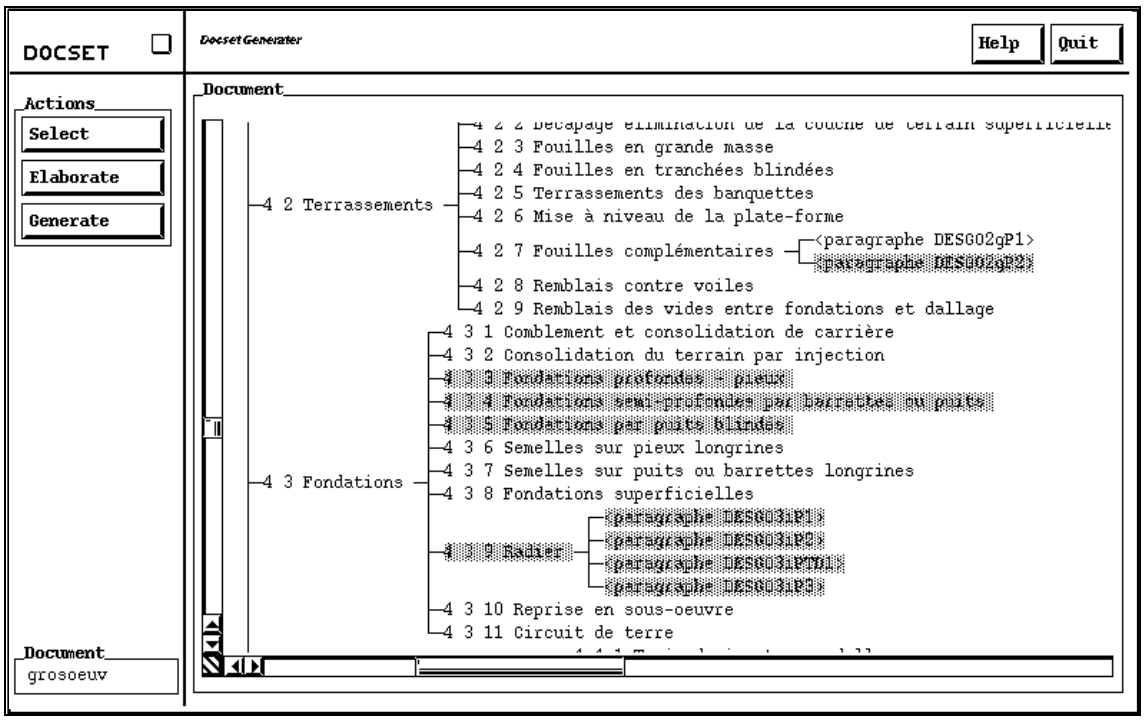

Fig. 12: Activation of the Predicates

Once the elaboration is terminated, the user can generate the project document in the desired form (SGML, RTF, Hypertext, etc.). The document created can then be accessed through the summary or by using eventual hypertext references which enable navigation from one division to another (internal or external to the document) of either a project documentor a construction standard.

9. CONCLUSION

To conclude this paper we would like to emphasise that the approach presented, while being original, also has great practical potential; it is hoped that its adoption will lead to an improvement in the quality of the construction project documents. Nevertheless, the authors would like to stress that they are aware of the practical difficulties involved in applying the proposed approach. It has taken approximately a decade for CAD packages to be fully integrated in engineering companies' current practices. Similarly, to some extent, moving from the

traditional document based approach to a model-based one is a difficult task that will take several years to achieve. Cultural factors play a key role in determining the research's success and the approach applicability. With this in mind, we must concede that issues surrounding business process re-engineering have not been deeply investigated.

The work presented in this paper is ongoing both in CSTB and the Information Technology Institute of Salford University. The research at Salford, through the EPSRC funded COMMIT project (Rezgui et al., 1995), aims to develop and define a more generic platform implementing the approach. This platform is intended to support all forms of model-based information in the distributed and multimedia environment.

It is hoped that the COMMIT project, which is supported by a UK steering group comprising regulation bodies, research institutions and industrials, will be able to demonstrate the technical, economic and sociological benefits that would be gained by adopting the proposed model based approach.

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ANNEX A: THE CCTP DTD

SGML is an ISO standard used for the description of both document models and DTDs (Document Type Definitions). A DTD contains the declaration of the numerous logical element types, used to structure a document, along with the description of their generic structure. A DTD can be used and shared by various document classes. It is obtained by abstracting the logical elements, along with their links, within the document. The following DTD, describing the logical structure of the CCTP document, was produced manually.

The Textual Units

Textual units enable the definition of 'parameters' entities. The aim is to allow, during the development of a given DTD, the grouping of elements names performing similar roles.

<!ENTITY % floating-element "manufacturer | model | notabene | variable" -- floating-element -->

<!ENTITY % reference "internal-reference | external-reference | regulation-reference | catalogue-reference" -- internal reference to the document, external reference to the document, reference to standards and regulations, reference to catalogues -->

<!ENTITY % floating-textual-unit "(%floating-element;) | (%reference;)" -- floating-textual-unit -->

<!ENTITY % standard-textual-unit "#PCDATA | paragraph | list | (%floating-textual-unit;)" -- standard-textual-unit -->

<!ENTITY % paragraph-textual-unit "#PCDATA | list | (%floating-textual-unit;)" -- paragraph-textual-unit -->

The global structure

The global structure describes document generic elements. Each element of the logical structure is declared. This declaration goes along with the description of the contents model of the documentary element.

<!ELEMENT cctp - - (cover-page, summary, body, annex*) -- the composants of a CCTP document (cover-page, summary, body, annex) -->

<!ATTLIST cctp id ID #REQUIRED >

<!ELEMENT cover-page - - (date,project-designation, document-designation, author) -- cover-page -->

<!ELEMENT summary - - (#PCDATA) -- document-summary -->

<!ELEMENT body - - (generalities, technical-instructions, technical-specifications, description-of-the-works, interfaces-between-workpackages) -- document-body -->

<!ELEMENT annex - - (title-3, paragraph*, division-4*) -- annex -->

<!ATTLIST (cover-page | summary | body | annex) id ID #REQUIRED >

The cover page structure

This section contains the description of the elements comprised within the cover page of the document. It contains the elements necessary to the identification of the document including Author(s), Date, Project name.

<!ELEMENT date - - (#PCDATA) -- date of document creation -->

<!ELEMENT project-designation - - (#PCDATA) -- designation of the project -->

<!ELEMENT document-designation - - (#PCDATA) -- designation of the CCTP -->

<!ELEMENT author - - (paragraph+) -- authors (engineering company) -->

The structure of the Body and of the Division

The CCTP's Body is composed of a hierarchy of divisions, each of which is described by its title and comprises a set of paragraphs. Specific elements have been created for the CCTP's main chapters. These (Generality, Specification, etc.) are similar in their internal structure and are equivalent to divisions of level 1.

<!ELEMENT division-2 - - (title-2, paragraph*, division-3*) -- divisionof level 2 -->

<!ELEMENT division-3 - - (title-3, paragraph*, division-4*) -- divisionof level 3 -->

<!ELEMENT division-4 - - (title-4, paragraph*, division-5*) -- divisionof level 4 -->

<!ELEMENT division-5 - - (title-5, paragraph*, division-6*) -- divisionof level 5 -->

<!ELEMENT division-6 - - (title-6, paragraph*) -- division of level 6 -->

<!ATTLIST (division-2 | division-3 | division-4 | division-5 | division-6) id ID #REQUIRED >

<!ELEMENT generalities - - (title-1, project-presentation, workpackages-list, company-obligations, contractual-documents-detail, planning, complementary-informations, technical-control, insurance, synthesis-committee, witness-committee, works-interaction) -- generalities -- >

<!ELEMENT technical-instructions - - (title-1, division-2+) -- technical instructions -- >

<!ELEMENT technical-specifications - - (title-1, division-2+) -- general technical specifications-->

<!ELEMENT description-of-the-works - - (title-1, division-2+) -- descriptionof the works -->

<!ELEMENT interfaces-between-workpackages - - (title-1, division-2+) -- interfaces-between-workpackages -->

The structure of the "Generalities"division

<!ELEMENT project-presentation - - (title-2, paragraph+) -- projet presentation-->

<!ELEMENT workpackages-list - - (title-2, paragraph+) -- workpackages list -->

<!ELEMENT company-obligations - - (title-2, paragraph+) -- obligations of the company->

<!ELEMENT contractual-documents-detail - - (title-2, paragraph+) -- nomenclature of contractual documents-->

<!ELEMENT planning - - (title-2, paragraph+) -- planning -->

<!ELEMENT complementary-informations - - (title-2, paragraph*, document-verification, drawings, construction-drawings, construction-site-manager, construction-site-cleaning,

procurement, works-control, highways) -- complementary informations -->

<!ELEMENT technical-control - - (title-2, paragraph+) -- technical control -->

<!ELEMENT insurance - - (title-2, paragraph+) -- insurance -->

<!ELEMENT synthesis-committee - - (title-2, paragraph+) -- synthesis-committee-->

<!ELEMENT witness-committee - (title-2, paragraph*, division-3*) -- witness-committee-->

<!ELEMENT works-interaction - - (title-2, paragraph*, implantation, incorporations, reservations, piercings, draughtproofings, fixation) -- works interaction -->

The structure of the "Complementary informations" division

The elements defined in this section are of level 3 and describe the complementary informations of division 1 "Generalities".

<!ELEMENT document-verification- - (title-3, paragraph+) -- document verification -->

<!ELEMENT drawings - - (title-3, paragraph+) -- drawings -->

<!ELEMENT construction-drawings- - (title-3, paragraph+) -- construction drawings-->

<!ELEMENT construction-site-manager- - (title-3, paragraph+) --construction site manager -->

<!ELEMENT construction-site-cleaning- - (title-3, paragraph+) -- construction-site-cleaning-->

<!ELEMENT procurement - - (title-3, paragraph+) -- procurement -->

<!ELEMENT works-control - - (title-3, paragraph+) -- works control -->

<!ELEMENT highways - - (title-3, paragraph+) -- highways -->

The structure of the "Interdedependent services" division

<!ELEMENT implantation - - (title-3, paragraph+) -- implantation -->

<!ELEMENT incorporations - - (title-3, paragraph+) -- incorporations -->

<!ELEMENT reservations - - (title-3, paragraph+, -- reservations -->

<!ELEMENT piercings - - (title-3, paragraph+) -- piercings -->

<!ELEMENT draughtproofings - - (title-3, paragraph+) -- draughtproofings -->

<!ELEMENT fixation - - (title-3, paragraph+) -- fixation -->

The description of the elements defining the Title

The Title element must exist for the division bit is optional for a paragraph.

<!ELEMENT (title-1 | title-2 | title-3 | title-4 | title-5 | title-6) - - (title-number, title-designation) -- division level title -->

<!ELEMENT (title-number | title-designation) - - (#PCDATA) -- title number and designation -->

Textual elements description

The textual elements constitute the elements composing paragraphs.

<!ELEMENT paragraph - - (&paragraph-textual-unit;)* -- paragraph -->

<!ATTLIST paragraph ID CDATA #OPTIONAL>

<!ELEMENT liste - - (item+) -- items list-->

<!ELEMENT item - - (&standard-textual-unit;)* -- list-item -->

<!ATTLIST item id CDATA >

Floating elements definition

<!ELEMENT (manufacturer | model | variable) - - (#PCDATA) -- manufacturer, product brand, variable ->

<!ELEMENT notabene - - (&standard-textual-unit;)* -- notabene -->

<!ATTLIST variable id ID #REQUIRED >

References definition

References elements define the internal and external links of document elements. From the References is generated the hypertext network of project documents.

<!ELEMENT (%reference;) - - (#PCDATA) -- reference -->

<!ATTLIST internal-reference refid IDREFS #REQUIRED >

<!ATTLIST (external-reference | regulation-reference | catalogue-reference) refid CDATA #REQUIRED>
