

SOFTWARE SYSTEMS FOR THE INTEGRATION OF DOCUMENTARY ENGINEERING WITHIN A CONSTRUCTION PROJECT

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Abstract

Numerous documents of diverse nature are involved in the construction process. Some of them such as building codes, examples of technical solutions, computation rules, define the legal context of a project. Others like technical specification documents or bills of quantities are generated by the engineering activities and often have a contractual importance. Quality of the laterers may be measured by their coherency with the regulation, with the documents previously approved, but also by their coherency with the construction project itself through the absence of errors, omissions or redundancies. Once elaborated, these documents should also prove ability to be used by various actors with specific needs or requests.

We describe here our approach to manage the production of these documents in tight connection with the engineering entities describing a construction project. Such a connection is based on a conceptual model of the project through its various systems and entities as proposed within the STEP framework. Such a connection relies also on a formal representation of the documents, pratically SGML Document Type Definitions, and on a set of document templates linked to the construction project model and from which the project documents will be derived : from a global set of documentary items, we will only retain the relevant sections towards a given project.

Then we present a software platform we develop to operate such an approach. This platform encompasses various modules taking in charge the elaboration of project data models according to the Express-G methodology, supporting the production of SGML DTDs and associated documents templates, providing some frames and facilities to link the project model and the document templates.

1. INTRODUCTION

The elaboration of the diverse types of textual documents associated to a construction project is a task as complex as that for graphic documents, both processes having to be run in parallel and in constant coordination. This complexity has a temporal aspect related to the many stages of a construction project and an organisational aspect due to the numerous actors implied.

The concern of a general engineering company is to produce at a given stage and for a given actor (client, authorities, contractors) textual documents of high quality, consistent with those previously approved and with the project description.

Among this wide subject, we limited our scope to the Detailed-Design/Call-for-Tender stages and to the related technical documents : the Full Specification Documents (FSDs). We find this choice relevant because of :



- the size of the FSDs in volume of text, number of documents, number of links between documents ;
- the high number of specialists of different disciplines involved ;
- their importance as contractual documents.

The quality of a FSD can only be obtained by a daily coordinated effort between the different actors and thanks to their knowledge of the building technical and legal standards. This quality is achieved through the absence of redundancies, the absence of inconsistencies, the absence of undescribed works and the absence of unnecessary articles. Therefore, the improvement in the quality of FSDs appears to lie with software tools which enable :

- the management of the internal consistency of the FSD of a given work package ;
- the management of the consistency between all the FSDs of a given project ;
- the management of the consistency between the FSDs and the Construction Standards;
- the hypertext browsing of the project documentary base with possible links to the related documentary bases in order to improve the access to the information ;
- perfecting the FSDs with regard to the description of works to be carried out and thus with the project data base.

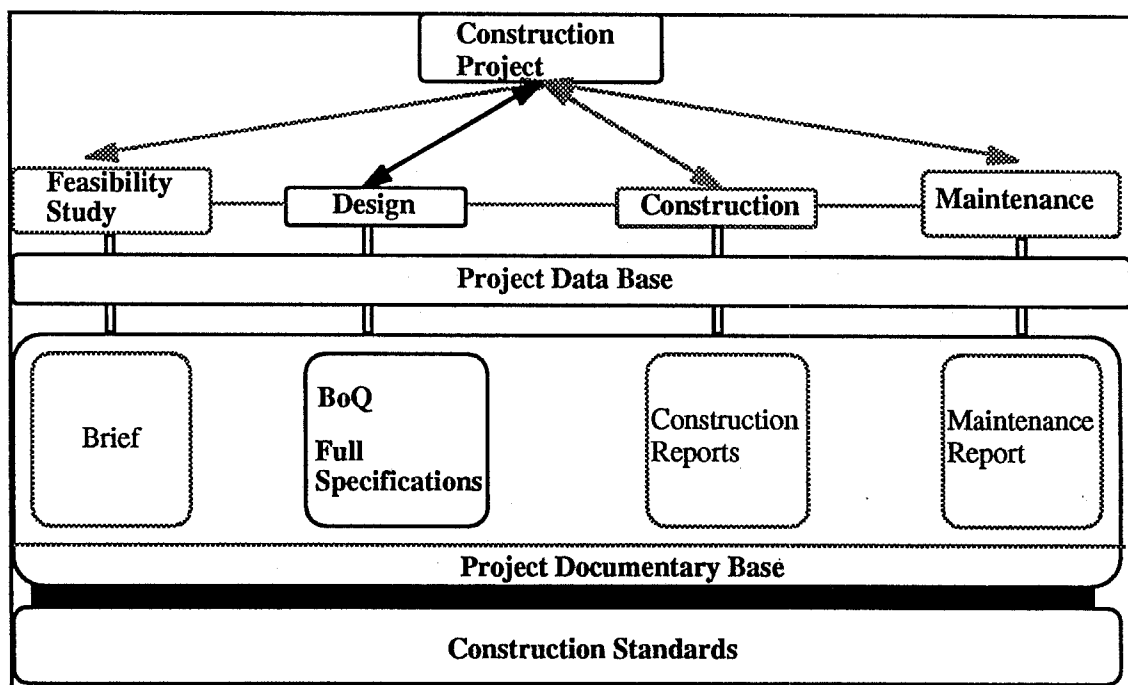


Fig 1. The documentary context of a construction project

In practice, an appropriate manipulation of information begins with a formal description of this information via the development of data structures or conceptual models [1]. This task of conceptual modelling can be facilitated by using adapted methodologies such as Niam or Express-G or by using software tools implementing these methodologies.

Thus we select and analyse different types of textual documents involved in the design and construction process to produce some conceptual models which are likely to support these documents. We derived some physical representations of these models according to various standard formats such as Express [2] schemas or SGML [3] Document Type Definitions (see chapter 2).

Then we focus on the production of project documents in relation with the project description and develop a Construction Project Reference Model (see chapter 3) and some Technical Specification Reference Documents gathering for some selected work packages, independently of a given project, all the divisions and paragraphs that might appear in this work package. We finally propose a knowledge base structure to support the link between the Construction Project Reference Model and the Reference Documents (see chapter 4).

The article ends with the presentation of a software demonstrator supporting the various paradigms aforementioned and handling the elaboration of a project document according to a given project (see chapter 5).

2. THE DOCUMENTARY MODEL

With the emergence of new demands following the computerisation of engineering documentation, it has become necessary to elaborate conceptual models tackling both the handling and the contents of the documents. Such a modelling work has to be carried out on the various components of a documentary system (including the documents themselves) and consists of the description of their structure [4] and their interacting relationships.

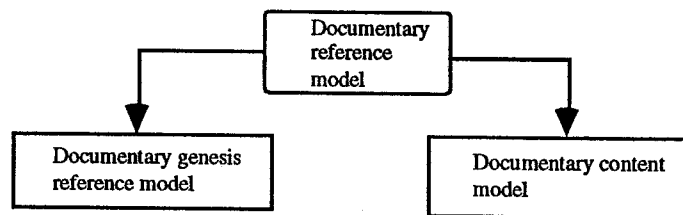


Fig 2. The genesis and content model of a document

2.1 THE DOCUMENTARY REFERENCE MODEL

The Documentary Reference Model 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, as well as its contents, leading to a Documentary Genesis Reference Model and a Documentary Contents Reference Model. The latest might be specialized into various Documentary Contents Applied Models to fit the diverse types of documents encountered : brief, full specifications, bill of quantities ... Note that we limit here the scope of the presentation to one of these, the Full Specification Applied Model.

2.2 THE DOCUMENTARY GENESIS REFERENCE MODEL

A document is a transitional and changing object defined within a precise stage of the Project Life Cycle. Generally, a document is related to many pre or co-elaborated documents within the Project Documentary Database. A Document has one or many authors. A document is described by general attributes such as a number, an index, a designation and a date of creation. A list of updated versions also keeps memory of any amendments made to the document. An indexing system may be associated to the document. A document is submitted for approval according to a defined circuit of examiners representing diverse technical or legal domains. Each examiner issues a statement which enables the document to be approved, refused or approved under reservation.

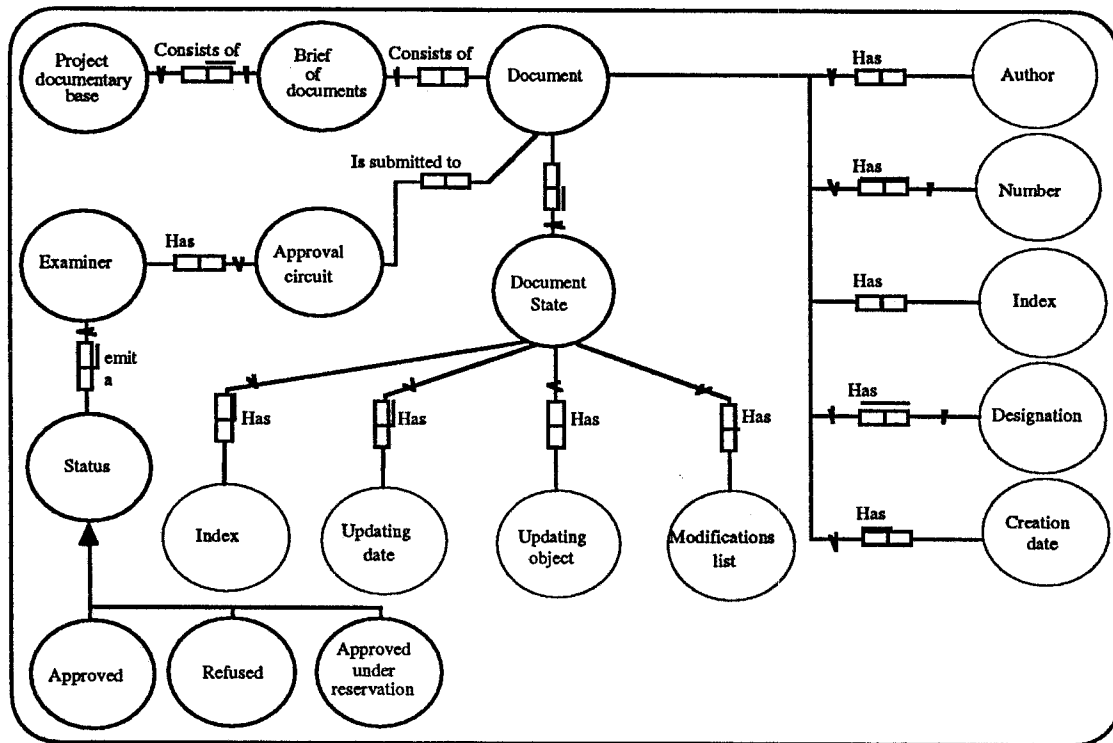


Fig 3. Graphical Niam View of the Genesis Reference Model

2.3 THE DOCUMENTARY CONTENTS REFERENCE MODEL

The contents of a written document consists of a cover page, a summary, a body and some appendices. The cover page usually carries the general attributes of the document (title, authors, version...).

The body of the document consists of a structure giving rise to divisions that are defined by their hierarchical level. The divisions have a title defined by a number as well as a label and present a similar contents model made up of paragraphs and lower level divisions.

A paragraph is merely composed of plain text and/or lists of items. Paragraphs and items may also include references (which may be internal to the document or external towards the documents of the project documentary database or other databases like the Building Regulation) as well as floating elements such as tables, figures or formulae.

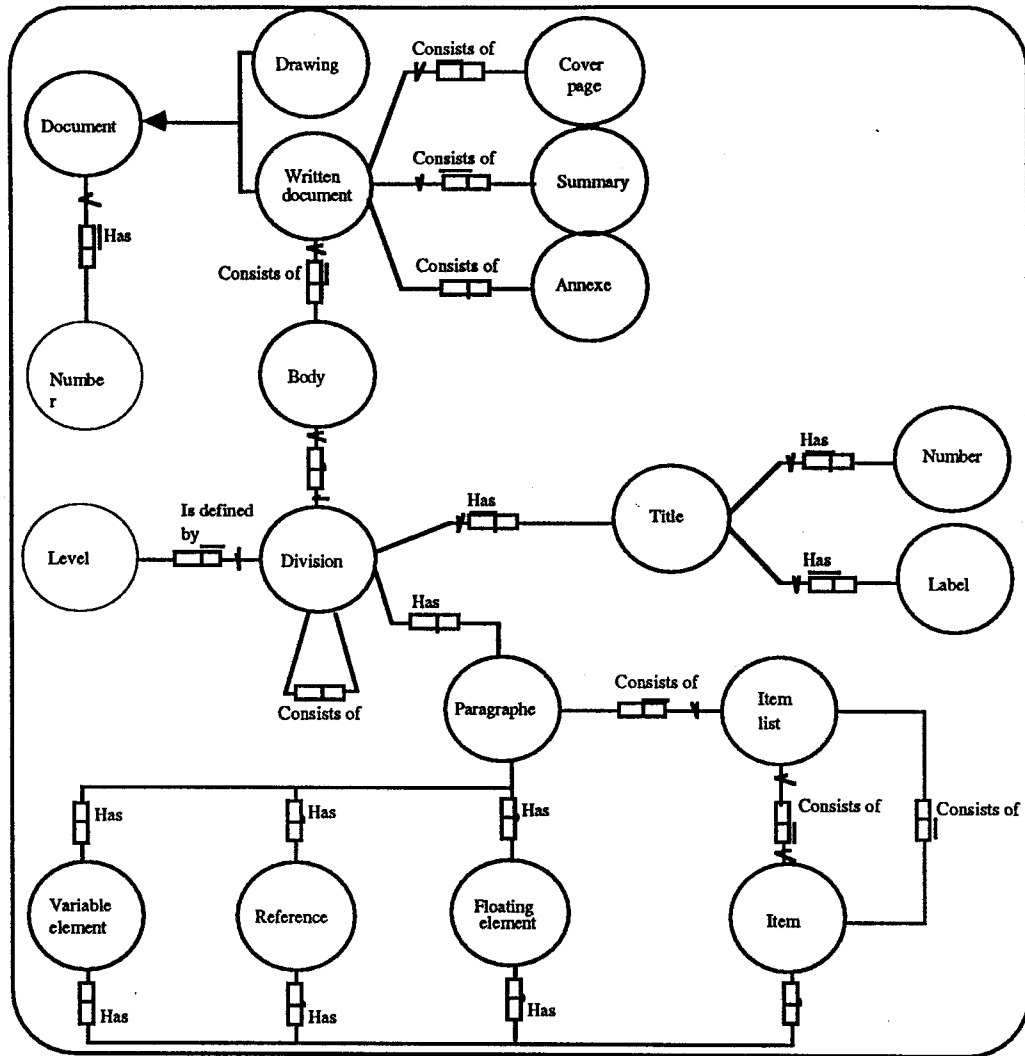


Fig 4. Graphical Niam View of the Contents Reference Model

2.4 THE FULL SPECIFICATION APPLIED MODEL

The FSDs carries precise answers to questions from the various actors of the project :

- the architect is concerned by the global control of the project in accordance with the brief and the detailed design ;
- the technical authorities can use the Full Specifications to approve the project and check the safety of the works undertaken, etc.

The analysis of the FSDs written by the same company and addressing several projects, reveals similarities both at their structural level and in the nature of their semantic content. A common structure can be extracted from this analysis. It consists of documentary divisions of different levels, each of which being 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.

3. THE CONSTRUCTION PROJECT REFERENCE MODEL

The Construction Project Reference Model (CPRM) developed at CSTB [5] is used as a basis for the generation of the project FSDs. It consists of a neutral data model through which the project actors communicate and exchange data. From this model can be derived Applied Project Data Models (APDM) by specialisation and inheritance mechanisms [6].

The CPRM is structured into several abstraction levels through which are described both the relevant generic entities composing the building systems and their relations. This modelling work is based on a top-down approach guided by the notion of view.

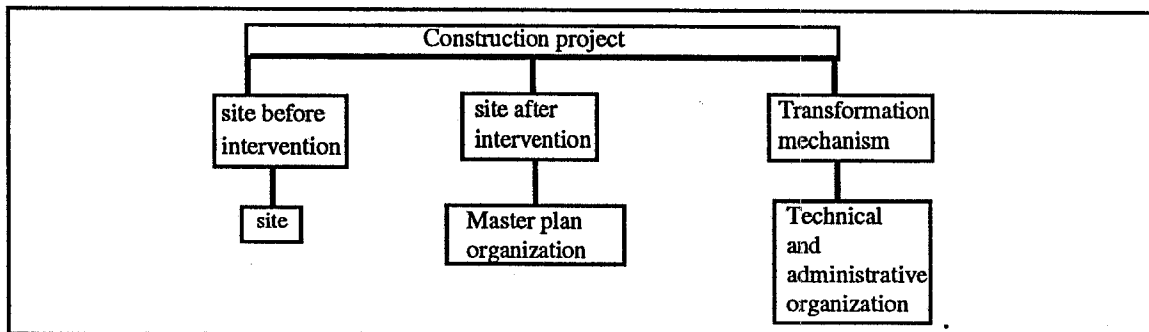


Fig 5. The three main branches of the CPRM.

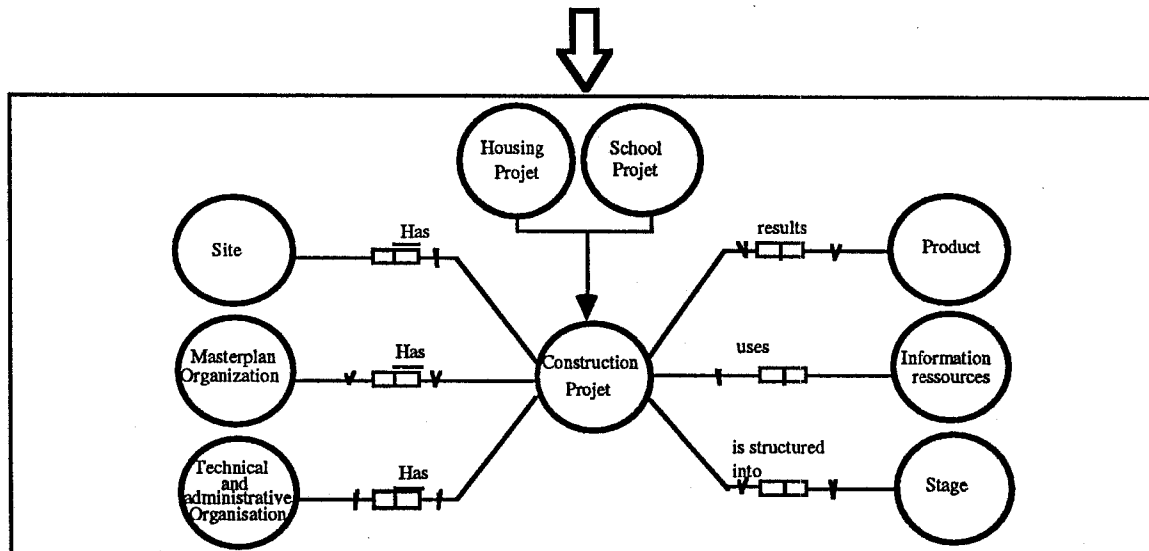


Fig 6. The main concepts of the construction project

As indicated in figure 5 the CPRM is structured into three main branches : the site, the master plan organization and the technical and administrative organization. The master plan organization comprises external spaces and buildings. The building is described via five systems : the structural system, the work system, the space system, the technical system and the separation system. The building entities describing the four FSDs cited above belong mainly to the work system. Moreover some entities are provided by the other complementary systems.

We insist on the fact that up to now numerous building data models have been developed. Moreover Building Application Protocols are being defined within the frame of the STEP project [7]. Thus, the CPRM briefly presented hereby will evolve according to all these works.

4. COUPLING THE DOCUMENTARY REFERENCE MODEL WITH THE CPRM

This chapter presents the approach and the different stages enabling the generation of the FSD of a construction project. The emphasis is particularly placed on the structure of the knowledge base allowing the building data model concepts to be associated to the documentary items of the reference FSD supporting their description.

4.1. PRESENTATION OF THE APPROACH

The reference FSD associated with each work package is an assembly of documentary items (divisions, paragraphs) where only a subset is relevant in establishing a project FSD. In fact, amongst the documentary items making up the reference FSD, many support the description of a series of works and potential procedures relating to the work package concerned. The existence of these documentary items is thus conditioned by the presence or use in the project of the works or construction processes that they describe. Furthermore, it will be seen in the reference FSDs that there are internal links with the document in question, or external ones with other reference FSDs or with documents of other databases like the Building Standards. Consequently, when the project FSD is produced, all internal and external links to documentary items already eliminated, should be suppressed. The reference FSD also contains variable elements (region, site) which should be specifically detailed for a given project.

We now propose the procedure envisaged whereby a reference FSD becomes a project FSD. This procedure begins with the selection of all the reference FSD items, relies on a knowledge base dedicated to the reference FSD associated to the following work packages : main structure, waterproofing, plumbing and external carpentry. It comprises three stages, each of which corresponding to a more and more discriminating level of document analysis.

4.2. ASSOCIATING THE REFERENCE FSD DOCUMENTARY ITEMS TO THE CONCEPTS OF THE CPRM

A project description relating to the site, to the use of certain materials or processes, to the presence of certain types of works enables the discarding of a series of associated documentary elements. Here, the emphasis is on the fact that some documentary divisions such as Full 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 prestressed concrete beam constitutes a necessary condition but is insufficient for the division which describes the instructions for the implementation of prestressed concrete to be deleted. This deletion is possible only if the project includes no prestressed 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 prestressed 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.
- Carpentry section
- the project includes a solar protection system;
 - the project includes shockproof glass;
 - the project includes curtain walls, 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 FSD and the CPRM. 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
predicate
  wording "Reinforced trench excavations"
  building-concepts ("reinforced_trench_excavations")
  target-elements ("DESGO2d")
  end-of-object

```

4.3. IMPLEMENTATION OF INTERNAL LINKS WITHIN THE DOCUMENT

A series of predefined 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', 'Technical specifications' and 'Limits of services' divisions. The EXPRESS schema which describes these dependent relationship 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

4.4. 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 wection

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 FSD 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

4.5. DOCUMENT VALIDATION

Having reached the final stage, the project FSD may eventually be slightly amended or completed on a textual level which does not challenge the structure of the document. The latter 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 chapter concerns the FSD document. It can, however, be applied to other written documents arising from a construction project.

5. THE DOCSET ENVIRONMENT

The CPRM briefly presented in chapter 3 has been created with the XP-EXPRESS-G tool of the XPDI platform. The expression of the building project in a form interpretable by the computer, is done by instantiation of the EXPRESS schema via the XP-SDAI manager. The schema and the associated model are stored in a persistent way in an O2 data base [8]. It is important to specify that, bearing in mind the descriptive nature of the FSD document, the number of instances of a work matters little. The panel below produced by XP-SDAI presents the entities of the Building model associated with the EXPRESS schema of the CPRM together with the corresponding project instances implemented.

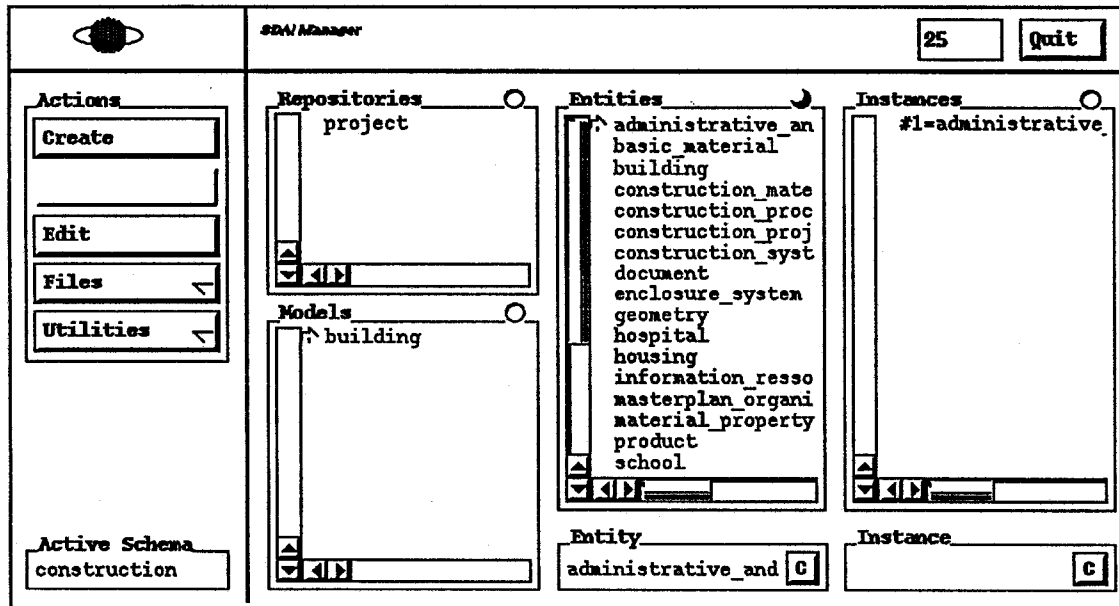


Fig. 7. SDAI manager

The panel below presents a partial view of the CPRM under the EXPRESS-G formalism.

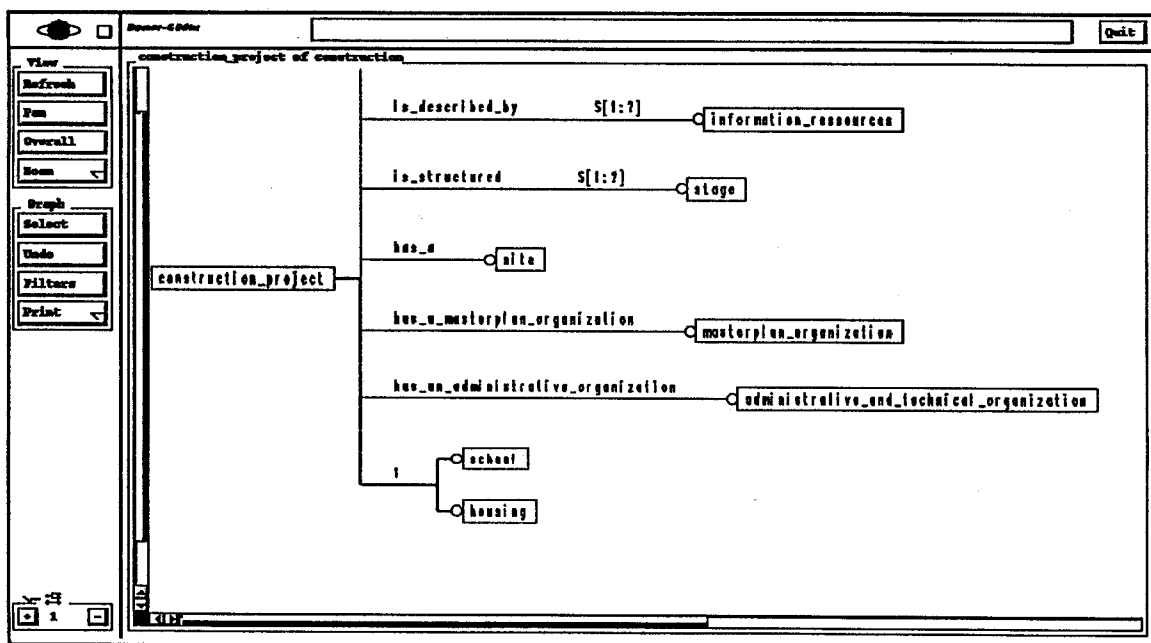


Fig. 8. Partial view of the CPRM under XP-EXPRESS-G

The XP-SDAI software tool allows the construction of an instance tree which conforms to the schema used. The panel below includes a project description form based on the instances of the CPRM.

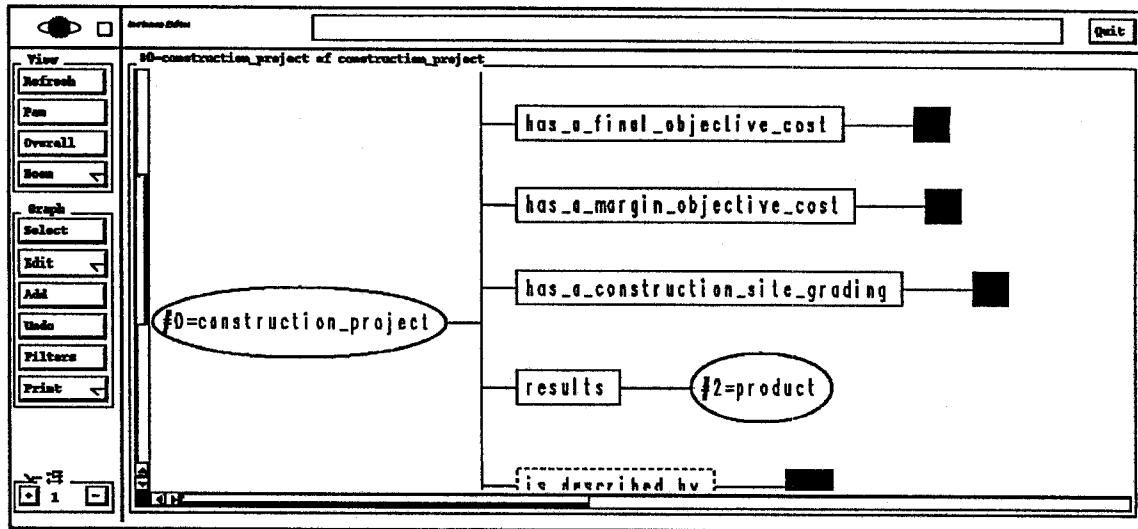


Fig. 9. Representation of the construction project in the form of an instance tree

The prototype implementing the approach presented in this paper consists of an extension of the DOCSET tool. As stated previously, every document constitutes an instance of the document class. This class identifies a precise type of document. Instance documents are themselves connected to a documentary base as illustrated in the panel below.

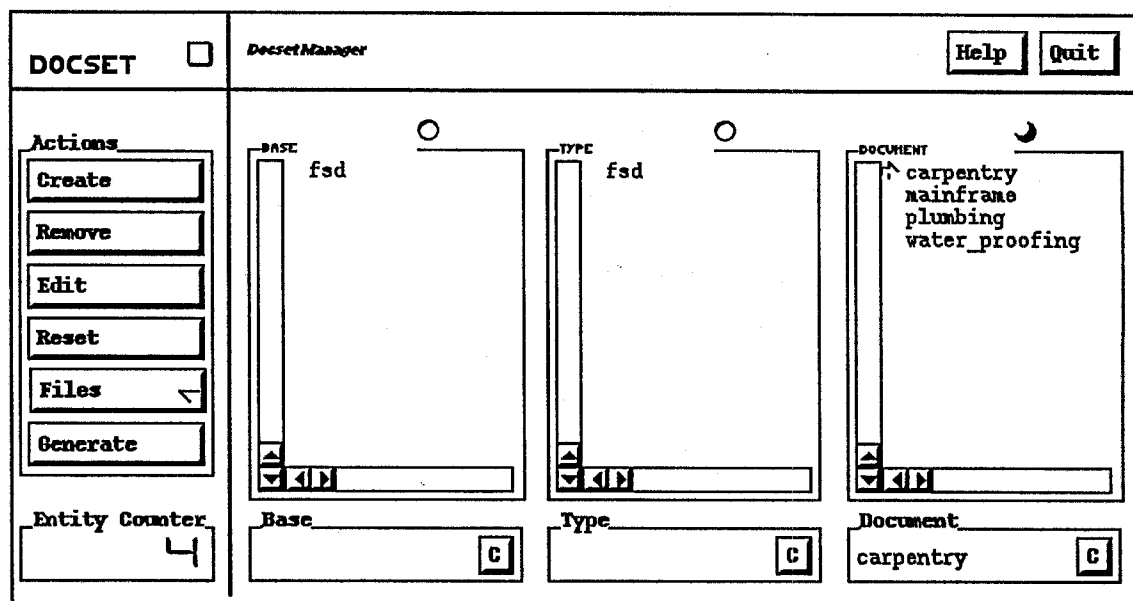


Fig. 10. Docset Manager panel

Firstly, Docset enables the editing of a reference document summary in a tree form. This function enables an exhaustive global vision of the contents as well as the logical structure of the document. The panel below presents a sub-section of the chapter "Description of Works" for the mainstructure work package.

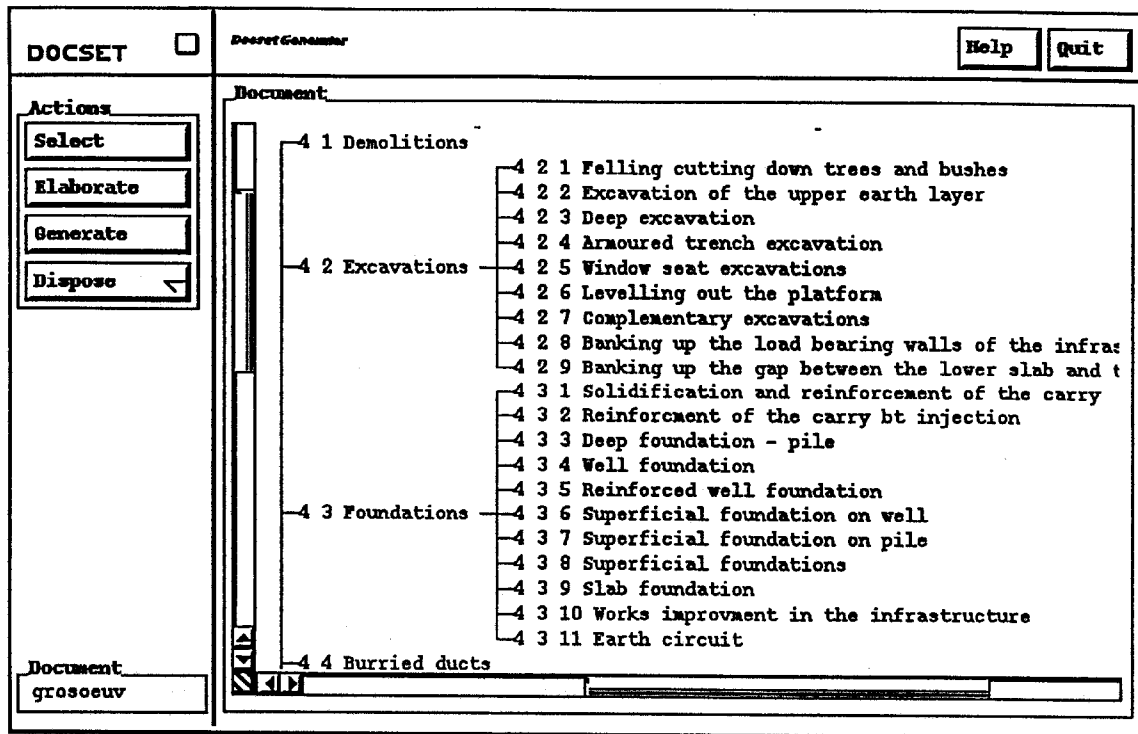


Fig. 11. Partial view of a reference FSD summary

The user then has the possibility of consulting or developing the information base of the active document. This information base is structured around four distinct levels, each one 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. The panel below corresponds to the waterproofing knowledge base.

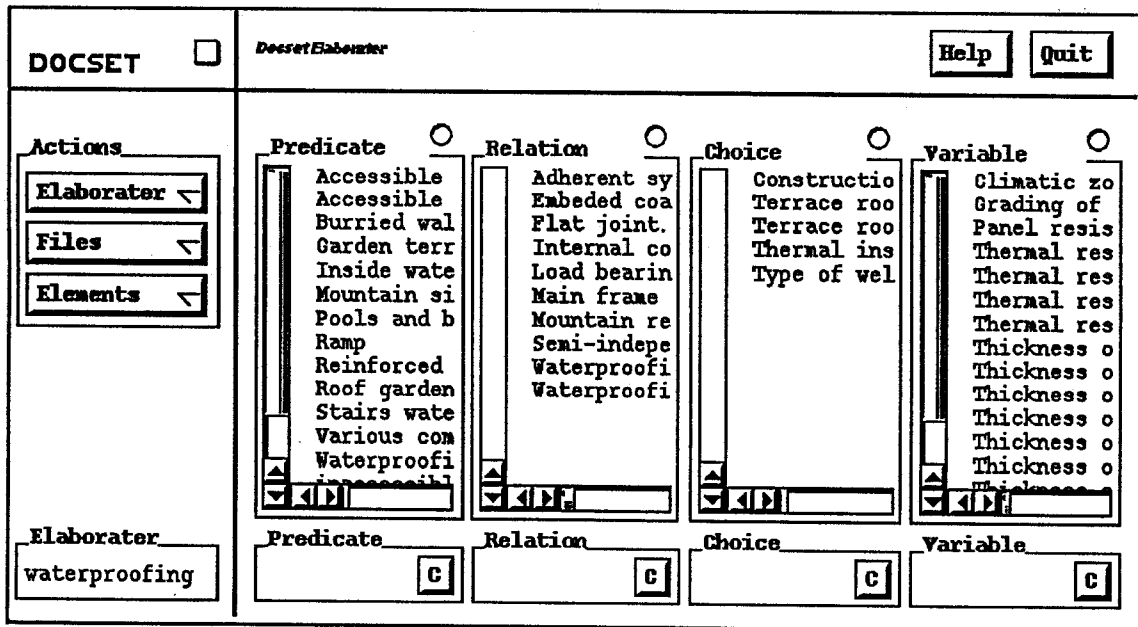


Fig. 12. Elaborater of the waterproofing FSD.

Two possible scenarios have been studied for the generation of the project FSD using the information base. The first scenario consists of an automatic generation via the instances of a building data model, in our case the CPRM. The principle is simple : it consists of verifying for each predicate if the building concept supporting the description of a documentary item of the Description of Works division has been instanciated. 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 elaborator 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" elements field and pointing towards the rest of the "Target IDs" elements document.

The following panel illustrates the case of a project including neither deep foundations nor semi-deep foundations. This evaluation may be done either manually (by activating the predicate concerned or by discarding nodes of the document tree), or automatically via the CPRM instances. The state of deletion is translated by a crossed out representation of the node concerned.

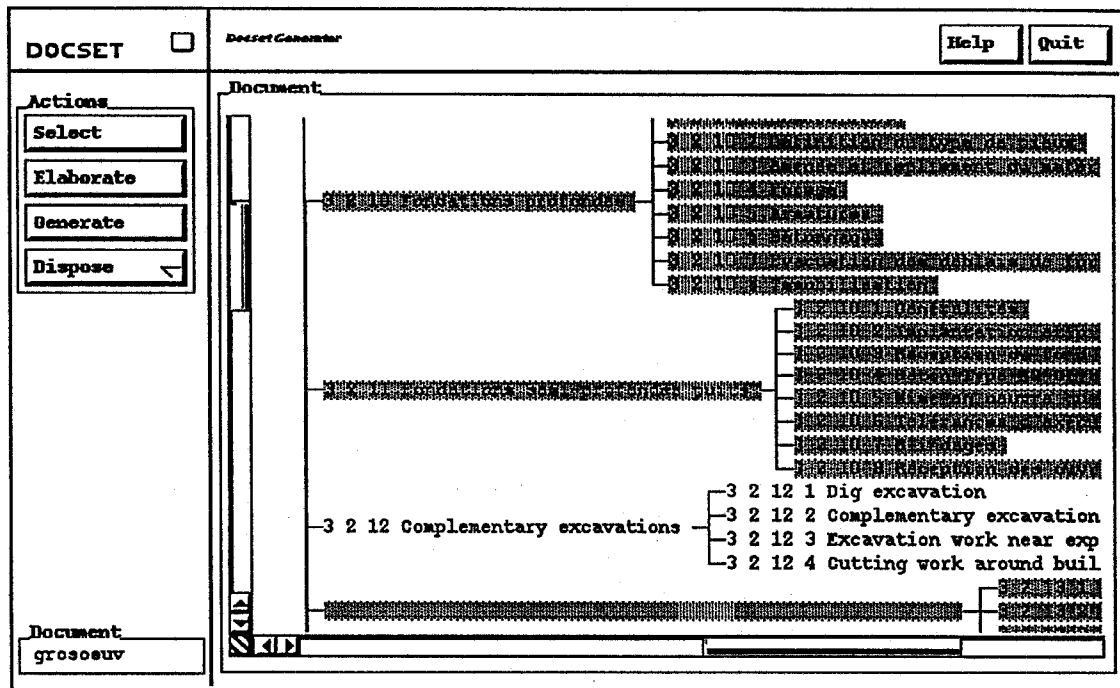


Fig. 13. Activating the predicates

The absence of deep foundations described by the identified division "DESGO3c" entails the deletion, via relationships, of the "DOCREFI2I", "SPEGO2j" and "SPEGO2m" divisions as indicated in the panel below. Interactive deselection of the "DOCREFI2I", "SPEGO2j" and "SPEGO2m" divisions entails the deselection of the whole sub-tree defined by this node. Similarly, the selection of a node entails the recursive selection of its fathers up until the root of the tree. Once the elaboration has been terminated, the user can generate the project document in the desired form (SGML, RTF, Hypertext, etc.). The document created can then be covered by access to the document from the summary or by using eventual hypertext references which send the reader from one division to another within the document, within another project document or to a document belonging to Construction Standards like the FARTEC database [9].

6. CONCLUSION

By way of conclusion to this paper we would like to emphasise the interest and the relevance of the approach presented hereby that augurs most probably an improvement of the quality of the construction project documents. The work presented in this paper will continue on the following points. The first point consists of the definition and the development of a more generic platform implementing the approach presented hereby. The second point will aim to demonstrate the first point and is based on the generation of work sheets, necessary for the contractors during the construction stage.

7. REFERENCES

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