THE BCXML: SUPPORTING ECOMMERCE AND KNOWLEDGE MANAGEMENT IN THE CONSTRUCTION INDUSTRY

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SUMMARY: *The eConstruct IST project has developed a communication technology called* Building and Construction eXtensible mark-up Language *(*bcXML*), which provides the European Building and Construction industry with a powerful but low cost XML-based language that primarily supports the eBusiness communication needed between clients, architects, engineers, suppliers, and contractors for the procurement of products, components, and services. BcXML also handle multi-lingual issues required when a virtual construction enterprise operates over the borders of the individual European member states. In order to enable the bcXML communication language to be demonstrated and tested, the bcXML Reference Architecture was designed and a prototype demonstrator was implemented. A number of client applications have also been implemented within the prototype and demonstrated the proof of concept for bcXML. Moreover, BcXML has been adopted as the format to import taxonomies into the construction-oriented ontology that is developed in the IST e-COGNOS project, which is implementing a KM infrastructure tailored to the construction needs. This paper describes the bcXML Reference Architecture, the implemented prototype and how bcXML has been used in e-COGNOS.*

KEYWORDS: *eBusiness, eCommerce/eProcurement, Taxonomy, Knowledge management.*

1. INTRODUCTION THE eCONSTRUCT APPROACH

The Building and Construction industry is continually striving to improve the building process and to deliver a higher quality product. This can lead to a reduction in defects or mistakes and a longer economic life for the resulting product. Improvements in the building process can reduce the construction period and cause less of an impact on the environment. Some of these improvements can be accomplished via better integration of the supply chain teams both during the construction period and during the building life cycle. Better integration can be achieved using improved communications that make use of open standards, structured communication between applications, and semantic or object based communication (unlike what can only be derived from drawings).

The eConstruct project[1] has focused its research work on supporting the e-Procurement services that are being provided by construction related Marketplaces or Portals. Currently, when using these Marketplaces or Portals, it can be difficult to find the exact product or component you are looking for. The eConstruct approach to handle this problem was centred on the development of an XML-based language called *Building and Construction eXtensible Mark-up Language* (*bcXML*). Through the bcXML, eConstruct has enabled the creation of "requirements messages" that can be interpreted by computer applications able to find suitable products that meet those requirements. In order to enable someone to find the required product quickly a taxonomy is used. In

[1] For more information, please see http://www.eConstruct.org.

eConstruct, a taxonomy is *a clear, formal and agreed definition of the BC objects, their properties and interrelationships involved in*. Such a taxonomy is used by both client and supplier side in matching requirements and (catalogue-based) solutions. This taxonomy was defined based on the meta-schema part of bcXML called the eXtensible Taxonomy Definition (XTD) which was harmonized with both ISO and IAI developments in this area. In that sense, the taxonomy used is just an XML instance of the XTD. It is promoted to a schema so that it can be further instantiated for the actual specifications.

In order to prove the usefulness of this approach, the bcXML Reference Architecture was developed and a prototype was designed and implemented to support a core set of e-procurement-related services. Such a prototype allows the generation of bcXML compliant catalogues, their management and the electronic procurement of products based on their properties.

The e-COGNOS IST project[2] has been developing a Knowledge Management (KM) infrastructure called *e-CKMI* tailored the Building and Construction (BC) sector in Europe. The e-CKMI is a Web-centred and ontology-enabled solution that has been implemented following the Web services model (Lima et al., 2003a). The e-COGNOS ontology has been developed taking into account relevant sources of inspiration, such as the IFC model, the bcXML MetaSchema/Taxonomy, the BS6100 Classification, the SUMO ontology, and the DAML+OIL language. The end users have been actively involved in the development of such an ontology, providing samples of documents, playing the role of ontology administrator, and finally checking if the ontological concepts suggested for their queries are the recommend ones.

In the e-CKMI development a key issue was the growth of the e-COGNOS ontology, i.e., the bigger, the richer (Lima et al., 2003b). The approach adopted was to develop a mechanism to automatically import bcXML-compliant taxonomies and include them within the ontology. The following reasons motivated this approach: (i) using the tools developed in eConstruct, the generation of bcXML-compliant taxonomies is a straightforward process using a simple excel spreadsheet; (ii) the bcXML XTD defines a meta-schema for the definition of taxonomies; and (iii) the existing bcXML-compliant (e.g. BS6100, Uniclass, and *bcBuildingDefinitions*) taxonomies can be easily incorporated into the e-COGNOS ontology. Moreover, bcXML is part of potential candidates evaluated in the CEN/ISSS (European Committee for Standardization / Information Society Standardization System) initiative called eConstruction, which gives more visibility and credibility to bcXML.

This paper describes the Reference Architecture, the respective prototype as well as the use of bcXML in e-COGNOS. It is structured as follows: section 2 describes the eConstruct approach supporting the development of the bcXML, section 3 presents the bcXML and the compliant taxonomy created by eConstruct, section 4 describes the bcXML Reference Architecture, section 5 discusses the bcXML prototype, section 6 describes the use of bcXML supporting the development of the e-COGNOS ontology, and finally the section 7 presents the major results achieved in eConstruct and points out the future work to be done.

2. THE eCONSTRUCT APPROACH

Today it is still not very easy to find information about products, components or professional services when using the Internet. In many cases there is no option but to consult paper based catalogues and trade indexes. Even when Internet-based services are available to find products/services, it is still difficult to create catalogue information in a format that can be re-used by more than one software application. The various actors in the BC arena (contractors, Web Portals, and product manufacturers) still are not able to share the information easily.

The goal of the eConstruct project was to develop, implement, demonstrate and disseminate a new Internet-based communication technology for the European BC industry. Although the Internet (plus Intranet and Extranet) potentially forms the ideal open, low-cost communication platform for the BC industry, in practice the Internet is currently only used in a limited way. When the eConstruct project was started in the beginning of year 2000, a major problem was "insufficient information structuring" because the Internet language HTML only supported freeform data exchange and therefore was not ideal for B2B[3] exchanges. In order to address this problem, the eConstruct project has developed a communication technology based on XML that helps the BC industry to handle more easily the electronic commerce.

The eConstruct project has focused on four major work areas, with the following purposes:

[2] The e-COGNOS is a 27 months IST project that has started July 2001. For more information, please see www.e-cognos.org.

[3] B2B: Business to Business.

- *Use Cases*: address business fields and typical use cases, where the benefits of the bcXML are urgently required;
- *Modelling Work*: provide a standard data structure, which served as the actual foundation supporting the bcXML specification;
- *Reference Architecture*: provide an architecture which supports the use cases and the associated communication information flows that are required to link the different applications;
- *Prototype implementations*: provide basic services, so that the communication can be established. The Reference Architecture was designed and implemented to prove that bcXML can be implemented and meet the needs of end users. This enabled both prototype applications and new types of application to show how the communication can be enabled in the addressed use cases. The prototype implementation also demonstrated how bcXML could be used to support the communication between various applications.

The bcXML was intended to be as open and useful as possible. Therefore, it has been designed in close co-operation with other related work and research projects as follows:

- The International Alliance for Interoperability (IAI) and their developments of ifcXML. This enabled the integration of the bcXML communication language with the Product and Data Technology (PDT) world.
- The IAI Dictionaries project XM7 aims to ensure the harmonisation of the IFC information model and ISO 12006 part 3 to ensure that the ISO standard can be used as a resource to facilitate the organised definition of IFC property sets;
- The current development of ISO PAS 12006 Part 3 – “Framework for object-oriented information exchange”. It defines an International Standard model that specifies a data structure for the storage of an extensible taxonomy containing language independent terms and their meanings. All terms are related to a key term expressed in English.
- BARBI is an extensible taxonomy that is structured according to the information model specification in ISO 12006 part 3. It provides Norwegian content to an ISO 12006 part 3 compliant database.
- Edibatec is a French national project for describing properties of manufactured products. Consistent product data definitions have been exported into an ISO 12006 part 3 compliant database to provide a French language form

3. THE BUILDING AND CONSTRUCTION EXTENSIBLE MARK-UP LANGUAGE

The *bcXML* supports the eBusiness communication needed between clients, architects and engineers, suppliers and contractors for the procurement of products, components and services. Moreover, it supports multiple languages that are needed when a virtual construction enterprise operates over the borders of the individual European member states. Additionally, it can be integrated with eCommerce applications. Indeed, the bcXML represents the approach adopted by eConstruct in order to handle the problems related to searching/finding precisely a given product/component when using marketplaces/portals devoted to the construction domain.

The bcXML modelling work was done at two levels:

- Generic level (meta-schema): bcXML has a generic component called the “eXtensible Taxonomy Definition” (XTD). It is industry sector independent that can be used as a template to define a taxonomy that is specific to a given sector. Figure 1 displays the Lite version of bcXML XTD, developed for implementation purposes;
- Taxonomy level (schema level): this is the level of the actual Taxonomy.

Figure 2 shows the *generic* XTD Meta-Schema component that defines how any taxonomy can be created. As already mentioned, the eConstruct project developed the *bcBuldingDefinitions* taxonomy specifically tailored to the Building and Construction needs, which can in turn be instantiated to create catalogue contents or the actual requirements and solutions messages. For example consider that a user wants to get quotations from a number of door suppliers that meet the following specification:

> *"5 no. 1 hour fire resistant, internal solid core doors, Ash veneered and lippings on both faces, door leaf height 2040mm and width 826mm"*

The user will probably notice that for each website found, he/she will have to use a different user interface to get to the required product. In many cases it will not be possible to locate a door that matches exactly the request, but a list of "candidate doors" available can be found.

The bcXML is primary capable of supporting simple eCommerce communication of products (materials, components, equipment, documents) and services inside or over the national borders. Users can specify the content of their messages (both supply and demand) in terms used in the building and construction industry. Simple, small and clear XML code is generated. Both B2C/C2B and B2B communication are provided. The bcXML is also able to communicate with external taxonomies that add more complex structuring mechanisms like specialisation, decomposition, or views. Most countries currently have several such taxonomies, mostly organised by sector (i.e. Building, Civil), or by discipline (i.e. architecture, structural design, HVAC engineering). Examples are the German Heinze Classification and the Dutch STABU Lexicon.

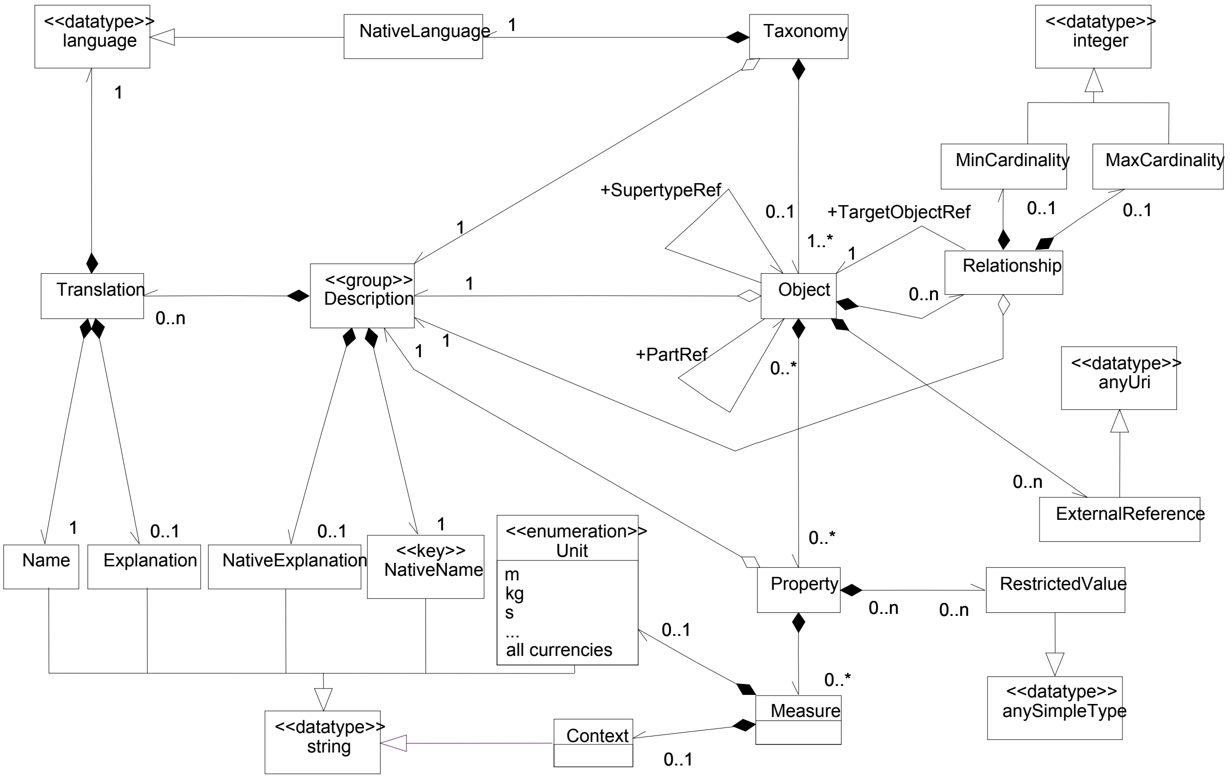


FIG. 1: bcXML XTD Meta-Schema.

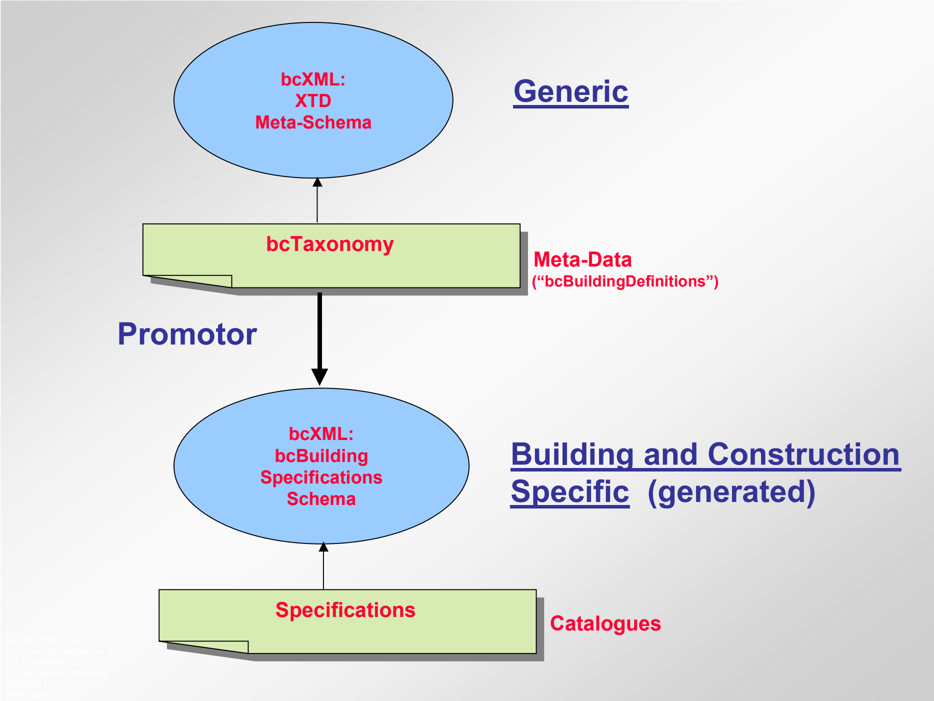


FIG. 2: The bcXML components.

4. THE BCXML REFERENCE ARCHITECTURE

The bcXML Reference Architecture for implementation purposes comprises three specific groups of components, namely the *Software Clients*, the *Kernel*, and the *Creation Tools* (Figure 3). The Software clients represent a number of tools that use the services provided by the Kernel. In turn, the Kernel components work together to manage consistently and to handle properly the bcXML-compliant taxonomies and user catalogues. Finally, the Creation tools provide a simple and user-friendly environment in which taxonomies and catalogues of products can be created.

The Software Clients are the following: (**i**) the *bcXML Browser (bcXB)* is based on a web browser and provides a textual-based interface for human interactions, giving access to the services offered by the Kernel components; (**ii**) the *VR Front-end* is based on a web browser and provides a graphical-oriented interface supporting the visualisation of products published in the catalogues; (**iii**) the *IfcBrowser/ProjectDB*, where the IfcBrowser provides an "on the fly" translation facility from IAI IFC models to VRML and HTML, both formats being viewed over networks (Intranet, Extranet or Internet). In turn, the Project Database links and/or integrates project data with bcXML resource data from one or more Resource DB Servers; (**iv**) the *CAS System* supports the sales process of real estate (apartments and houses) to end customers by using a specific application, which allows sales persons to easily present the objects to be sold to their customers in an attractive manner based on always up-to-date product and catalogue data. The CAS System has in the *CAS Catalogue Definer* a tool for creating its private catalogues.

The Kernel is composed of the *Resource DB Server* (RS), the *Supplier Catalogue Server* (SCS), and the *Taxonomy Server* (TS). The RS supports the searching process based on the bcXML compliant queries received from the Software Clients. The SCS is the "gatekeeper" that provides access to the bcXML compliant suppliers' catalogues. The TS takes care of all the issues related to bcXML-compliant taxonomies (e.g. what are the properties of a given product, what are the sub-products attached to it). In order to avoid having a single SCS handling all the catalogues, the RS can indeed manage a network of SCS, taking advantage of the distributed environment in which the Prototype is working. There is one *default* SCS but an unlimited number of SCSs maybe registered in the RS and managed properly.

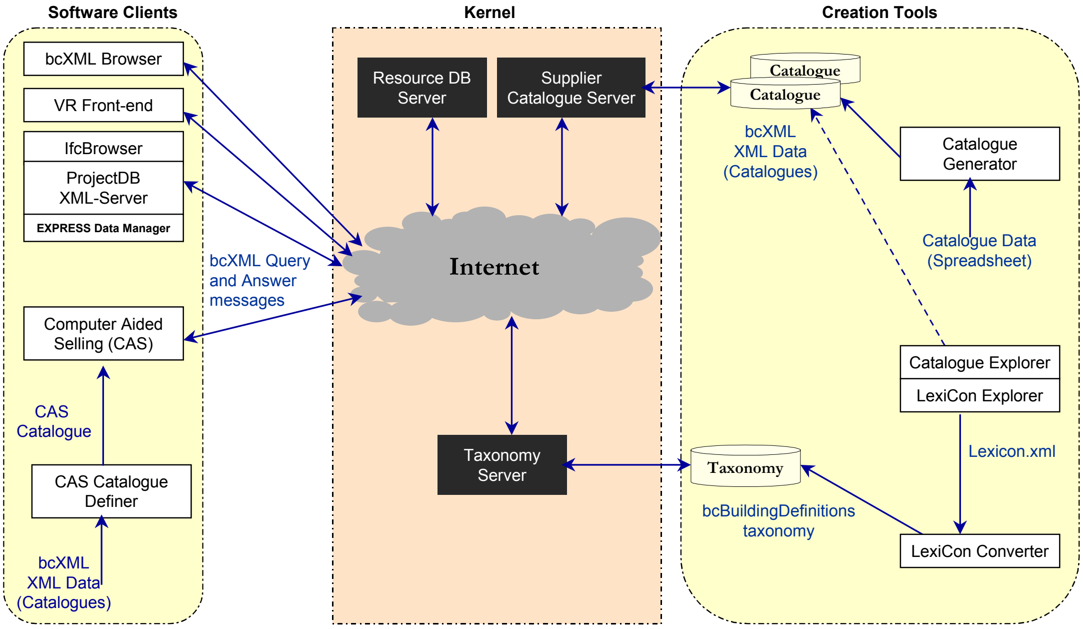
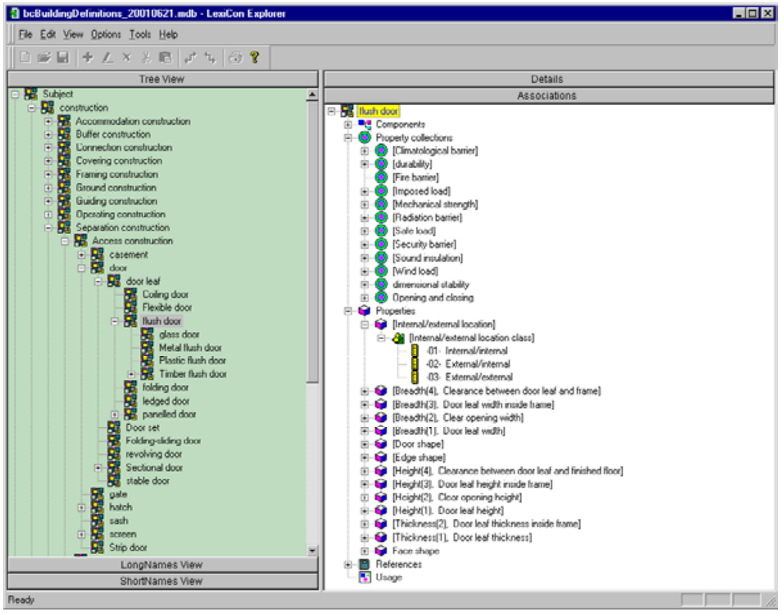


FIG. 3: The bcXML components.

The Creation tools are the following: the *Catalogue Generator*, the *LexiCon Explorer*, and the *Lexicon Converter*. In order to generates a catalogue bcXML-compliant; the Catalogue Generator uses an excel spreadsheet as input (created by the user, such a spreadsheet contains the catalogue of products in a very simple format) and a taxonomy specification. The LexiCon Explorer is a graphical taxonomy editor that is bcXML compliant. The Lexicon Converter is a component that generates the taxonomies.

4.1 Defining the Taxonomy

Figure 4 presents part of the bcBuildingDefinitions taxonomy specialisation tree that has been expanded for the object door. On the right hand side the definition for a Flush Door is displayed and it shows some of the properties that are associated this type of door.


bcBuildingDefinitions_20010621.mdb - LexiCon Explorer
File Edit View Options Tools Help
Tree View
Details
Associations
LongNames View
ShortNames View
Ready

```
Subject
  construction
    Accommodation construction
    Buffer construction
    Connection construction
    Covering construction
    Framing construction
    Ground construction
    Guiding construction
    Operating construction
    Separation construction
      Access construction
        casement
        door
          door leaf
            Coiling door
            Flexible door
            flush door
              glass door
              Metal flush door
              Plastic flush door
              Timber flush door
            folding door
            ledged door
            panelled door
          Door set
          Folding-sliding door
          revolving door
          Sectional door
          stable door
        gate
        hatch
        sash
        screen
        Strip door
```

```
flush door
  Components
  Property collections
    [Climatological barrier]
    [durability]
    [Fire barrier]
    [Imposed load]
    [Mechanical strength]
    [Radiation barrier]
    [Safe load]
    [Security barrier]
    [Sound insulation]
    [Wind load]
    dimensional stability
    Opening and closing
  Properties
    [Internal/external location]
      [Internal/external location class]
        -01- Internal/internal
        -02- External/internal
        -03- External/external
    [Breadth(4), Clearance between door leaf and frame]
    [Breadth(3), Door leaf width inside frame]
    [Breadth(2), Clear opening width]
    [Breadth(1), Door leaf width]
    [Door shape]
    [Edge shape]
    [Height(4), Clearance between door leaf and finished floor]
    [Height(3), Door leaf height inside frame]
    [Height(2), Clear opening height]
    [Height(1), Door leaf height]
    [Thickness(2), Door leaf thickness inside frame]
    [Thickness(1), Door leaf thickness]
    Face shape
  References
  Usage
```

FIG. 4: Flush Door definition in the LexiCon Explorer.

Other information such as the objects that can make up the composition of a flush door are also defined in the taxonomy. Typical components could be the doors ironmongery and glazing panels.

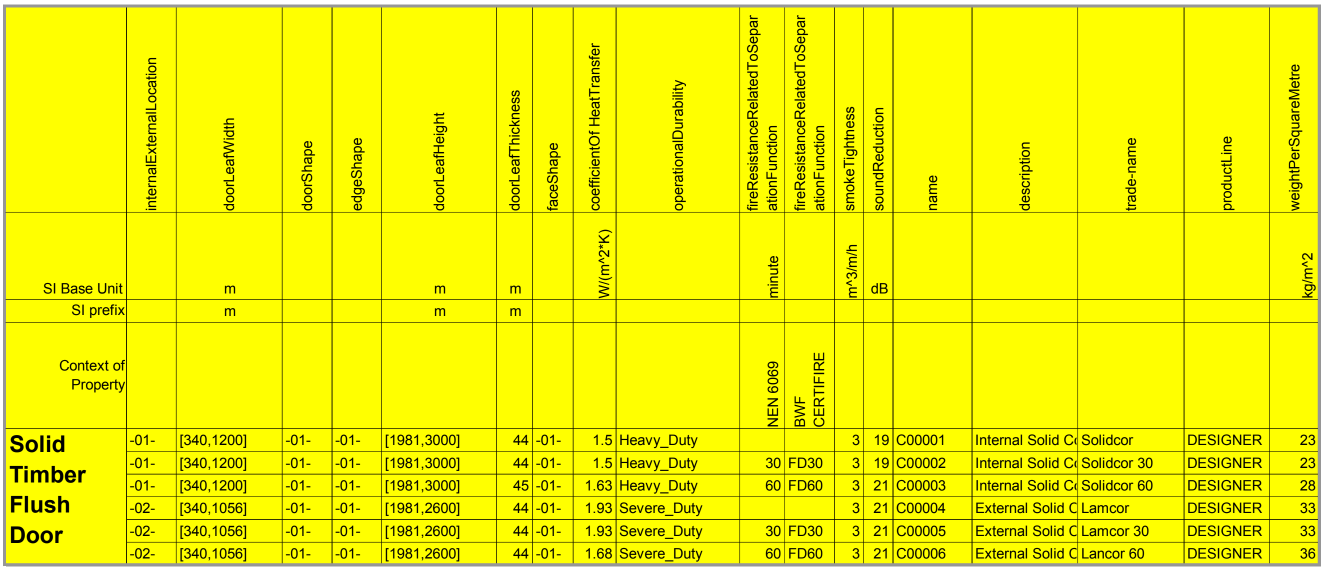
4.2 Creating Catalogue Content

Within the eConstruct project a number of methods to create catalogue content were used:

- The Catalogue Generator was used in order to quickly generate product catalogues that were created using MS Excel spreadsheet;
- The Catalogue Explorer was implemented as a component of the LexiCon Explorer application that was used to define the Taxonomy. Its purpose is to provide a tool for building an electronic catalogue of products that is based on the taxonomy in the LexiCon. The contents of a catalogue can be exported into an XML file, structured according to the LexiCon XML format.
- The Catalogue Definer is part of the CAS application and can import catalogue content information in the form of a bcXML catalogue XML data file or using SOAP and accessing a Resource DB Server in the bcXML Reference Architecture.

Only the Catalogue Generator is described here. It uses a MS Excel spreadsheet to define and then export bcXML compliant catalogues. It was developed in order to quickly create catalogues using a very simple tool, which in fact provided the users with a simple and low cost way to create their catalogues.

In an Excel spreadsheet-based catalogue the properties are defined in the columns and the products in the rows. Properties in a catalogue can be defined a single values, ranges or lists of possible values. Properties can also be defined in different contexts, for example the fire resistance of the door will have different fire rating tests done in Holland and the United Kingdom as shown in Figure 5 where the "fireResistanceRelatedToSeparationFunction" property is defined with 2 contexts. The spreadsheet catalogue is parsed by an application tool that automatically generates the equivalent bcXML compliant catalogue, which can be made available to the end users through the prototype.



	internalExternalLocation	doorLeafWidth	doorShape	edgeShape	doorLeafHeight	doorLeafThickness	faceShape	coefficientOf HeatTransfer	operationalDurability	fireResistanceRelatedToSeparationFunction	fireResistanceRelatedToSeparationFunction	smokeTightness	soundReduction	name	description	trade-name	productLine	weightPerSquareMetre
SI Base Unit		m			m	m		W/(m^2*K)		minute		m^3/m/h	dB					kg/m^2
SI prefix		m			m	m												
Context of Property										NEN 6069	BWF CERTIFIRE							
Solid Timber Flush Door	-01-	[340,1200]	-01-	-01-	[1981,3000]	44	-01-	1.5	Heavy_Duty			3	19	C00001	Internal Solid C	Solidcor	DESIGNER	23
	-01-	[340,1200]	-01-	-01-	[1981,3000]	44	-01-	1.5	Heavy_Duty	30	FD30	3	19	C00002	Internal Solid C	Solidcor 30	DESIGNER	23
	-01-	[340,1200]	-01-	-01-	[1981,3000]	45	-01-	1.63	Heavy_Duty	60	FD60	3	21	C00003	Internal Solid C	Solidcor 60	DESIGNER	28
	-02-	[340,1056]	-01-	-01-	[1981,2600]	44	-01-	1.93	Severe_Duty			3	21	C00004	External Solid C	Lamcor	DESIGNER	33
	-02-	[340,1056]	-01-	-01-	[1981,2600]	44	-01-	1.93	Severe_Duty	30	FD30	3	21	C00005	External Solid C	Lamcor 30	DESIGNER	33
	-02-	[340,1056]	-01-	-01-	[1981,2600]	44	-01-	1.68	Severe_Duty	60	FD60	3	21	C00006	External Solid C	Lancor 60	DESIGNER	36

FIG. 5– Typical Door Catalogue Content

4.3 The Resource DB Server

The RS provides a higher-level mechanism for supporting the search for products across multiple catalogues and even through a number of different SCSs that have been registered in the eConstruct domain. The searching process is requested by the Software Clients as shown in Figure 6. The RS receives bcXML complaint queries coming from the software clients searching for products in the bcXML compliant catalogues and provides the appropriate answers. It is important to notice that in order to treat the queries the RS needs to interact with the TS, since questions such as product structure, multi-lingual aspects, and other taxonomy-related issues are fully handled by the TS.

The RS can manage a network of SCSs, with each SCS able to manage several bcXML compliant catalogues. The RS can be viewed as a kind of "gateway" that provides access to multiple catalogues stored remotely, eventually in different countries. The support provided by the RS in the searching processes guarantees that the seeker uses his/her native language to search in a number of catalogues stored remotely and published in other languages. Since the TS supports multiple languages the results can always be provided in the language chosen by the end-user.

The users can contact directly and individually each one of the SCSs that are available in the eConstruct domain. However, only the RS knows the entire list of SCSs available and is able to perform multiple searches using all of them. This facility is lost when the user interacts directly with one given SCS.

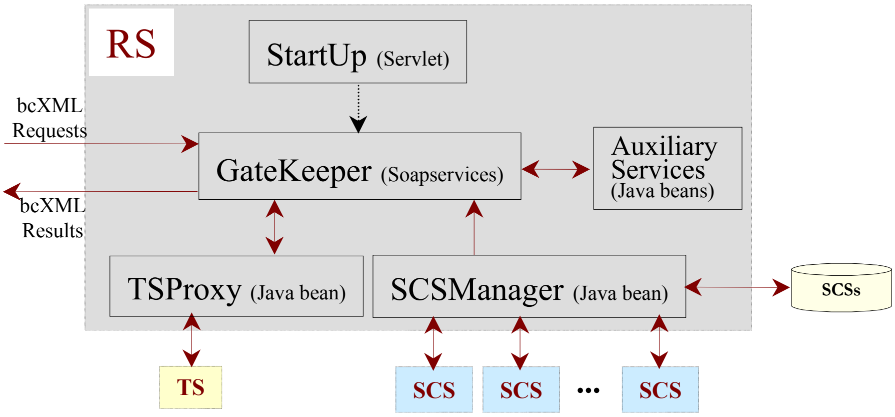


FIG. 6: RS Internal Architecture.

The RS Internal Architecture (figure 6) comprises the following components: the *StartUp* (a servlet); the *GateKeeper* (a set of SOAP services), the *SCSManager* (a Java bean), the *TSProxy* (another Java bean), and some *Auxiliary Services* (a set of Java beans). The *StartUp* servlet performs some initialisation actions. The *GateKeeper* receives the bcXML requests sent by the software clients and dispatches the execution flow either to a given SCS or to the *SCSManager*, according to the service being requested. The *GateKeeper* is a set of SOAP-based services that receive bcXML requests and send back bcXML results. The *SCSManager* manages all the issues related to the list of SCSs registered in the RS. There is at least the *default* SCS in the list which guarantees that the RS runs properly. Finally, the *TSProxy* interacts with the TS in order to handle all the taxonomy-related matters detected during the RS operation. The *Gatekeeper* is deployed in a SOAP server, which works linked to the TOMCAT servlet container.

4.4 The Taxonomy Server

This component deals with all the taxonomy-related requests. It supports the operation of RS, SCSs, CAS system, and Project DB server. The only component visible in Taxonomy Server (TS) is the taxonomy interface, which supports the interaction with the human operator.

In terms of interactions the TS is a reactive component in the sense that it only receives the requests from the other applications and sends the answers back to them. The TS never takes the initiative in any communication process. It is also important to note that the taxonomy interface is intended to accept both questions phrased in bcXML and direct SOAP requests. The former means that you can send a bcXML file with a door specification and that the taxonomy elaborates on that by adding as much information as possible. The latter means that the taxonomy server understands messages such as "give me a list of all the objects you have".

4.5 The Supplier Catalogue Server

The SCS works as a "front end" giving access to the catalogues created by the suppliers that are made available in the eConstruct domain. Basically, a SCS has to be able to receive requests about the products existing in the catalogues. These requests may come from both human operators and application tools. In order to avoid duplicating functionalities, the bcXB will provide the human interface for the SCS, which means that the users can have access to the SCSs through some services included in the bcXB home page. Therefore, the SCS has to provide only a SOAP-based interface for all the software clients, including the bcXB. It is worth noticing that the existing SCS implementation carried out in order to put the bcXML prototype working properly is regarded as one possible implementation of the SCS component. Other implementations can be provided by other organisations as long as they support the SCS-related services defined in the respective API.

The SCS was designed following the same approach adopted in the RS. As shown in Figure 7, it comprises the following components: the *StartUp* (a servlet), the *GateKeeper* (a set of soap services), the *CatalogueManager* (a Java bean), the *TSProxy* (another Java bean), and some *Auxiliary Services* (a group of Java beans). The *StartUp* servlet performs the required initialisation actions. The *GateKeeper* receives the bcXML requests sent by the software clients and dispatches the execution flow to the *CatalogueManager* which will process the request and perform the required actions in order to satisfy that request. The *GateKeeper* is, indeed, a set of SOAP-based services that receive bcXML requests and send back bcXML results. Finally, the *TSProxy* (Java bean) interacts with the TS in order to handle all the taxonomy-related matters detected during the SCS operation.

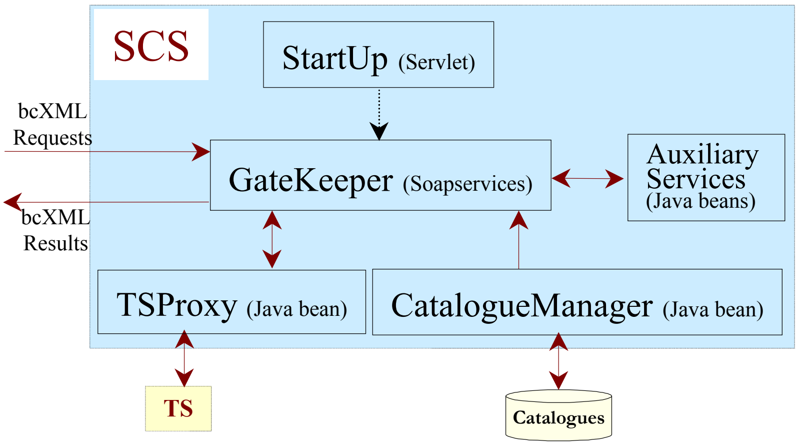

SCS
StartUp (Servlet)
bcXML Requests
bcXML Results
GateKeeper (Soapservices)
Auxiliary Services (Java beans)
TSProxy (Java bean)
CatalogueManager (Java bean)
TS
Catalogues

FIG. 7: SCS internal structure.

4.6 The bcXML Browser (bcXB)

The bcXB is composed of two modules, namely the *Controller* and the *Viewer* (Figure 8). The former plays the role of a “gatekeeper” that receives the users’ request as an HTTP command and sends it to the targeted component. The latter displays the results produced by the execution of the request received. Depending on the service selected by the user, the HTTP command is either converted in a SOAP request and sent to the right Kernel component (RS, SCS, or TS) or it is transformed in a display request which is sent to the Presentation Viewer. Either way, the result will be a web page displayed to the user presenting the results for his/her request.

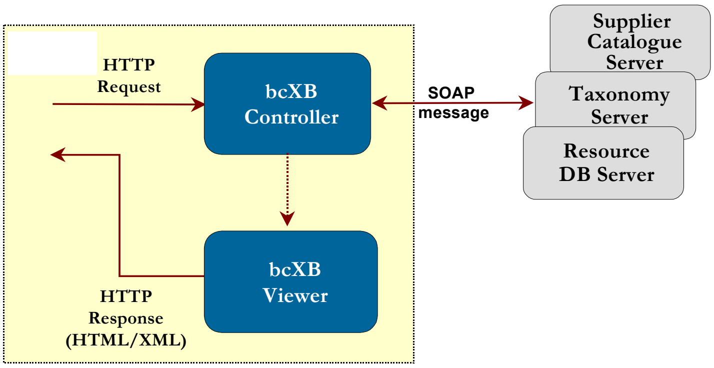


FIG. 8: The bcXB Components.

Whilst the Controller relies on a set of servlets, the Viewer is based on a set of XML files and their respective XSL templates (figure 9). The *StartUp* (the first servlet) performs some initialisation-related tasks to guarantee that bcXB starts working in the right way. In turn, the *EntryPoint* (the second servlet) receives the users’ selections and processes them. Depending on the service requested, it calls the *MgmtProcessRequest* (the third servlet) or the *Viewer* (a Java bean). The former activates the *Caller* (another Java bean), which is responsible for calling the appropriate Kernel component able to handle the service being requested. The *Caller* gets back the results generated for this request and sends them to the *MgmtProcessRequest*, which in turn will pass them to the Viewer that prepares and displays them to the user. In fact, the results displayed by the Viewer are (bc)XML-compliant. As such, it relies on XSL tag library to handle properly the display of some XML-compliant pages and their respective XSL templates.

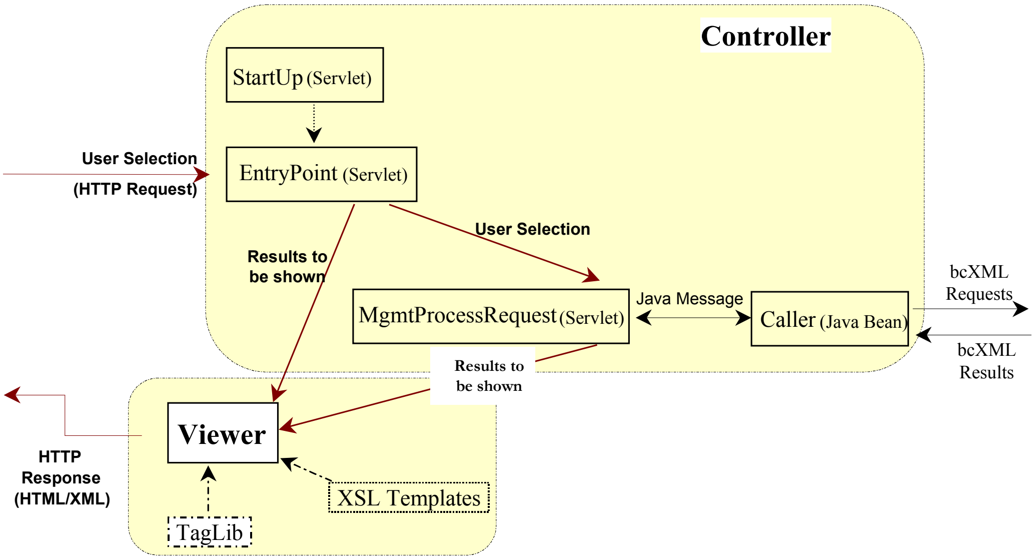


FIG. 9: Internal view of bcXB.

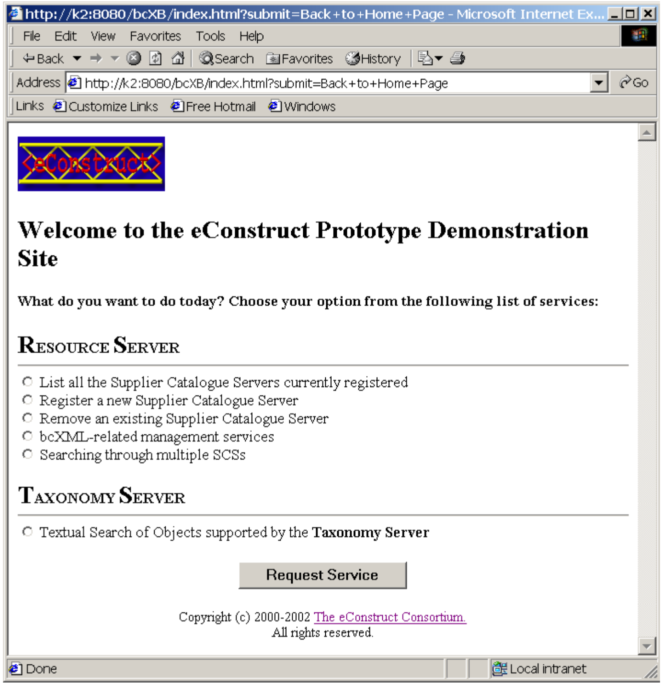
5. THE BCXML PROTOTYPE

Although the Prototype comprised a greater number of components, only some of them are described here, namely the Client applications and the Kernel components. The Client applications are the following: the bcXB, the VR Front End, and the CAS system. The Kernel components, described together with the bcXB, are the RS, the TS, and the SCS.

5.1 The bcXML Browser

The Figure 10 shows the entry page of the bcXML Browser user interface that runs in a standard web browser and which gives access to the services provided by the Kernel components[4]. Through this page the bcXB offers three services to access the RS in order to handle the management of the SCS list (*List all the Supplier Catalogue Servers currently registered*, *Register a new Supplier Catalogue Server*, *Remove an existing Supplier Catalogue Server*). The next one, *bcXML-related management services*, leads to the SCS entry page. The *Searching through multiple SCSs* gives access to the search page in the RS, from where the user is able to search through multiple SCSs and multiple catalogues. Finally, the TS-related service supports a *Textual Search of Objects*.

[4] A working Prototype can be accessed at the following web site: http://www.bcxml.org/bcxb/index.html.


http://k2:8080/bcXB/index.html?submit=Back+to+Home+Page - Microsoft Internet Ex...
File Edit View Favorites Tools Help
Back Search Favorites History
Address http://k2:8080/bcXB/index.html?submit=Back+to+Home+Page
Go
Links Customize Links Free Hotmail Windows
<eConstruct>
Done
Local intranet

Welcome to the eConstruct Prototype Demonstration Site

What do you want to do today? Choose your option from the following list of services:

Resource Server

○ List all the Supplier Catalogue Servers currently registered
○ Register a new Supplier Catalogue Server
○ Remove an existing Supplier Catalogue Server
○ bcXML-related management services
○ Searching through multiple SCSs

Taxonomy Server

○ Textual Search of Objects supported by the **Taxonomy Server**

Request Service

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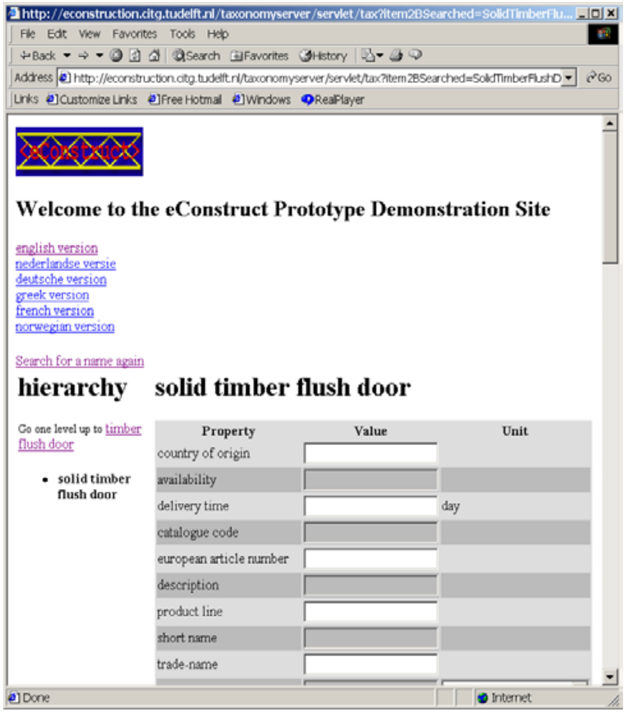
FIG. 10: bcXML Browser entry page.

One of the main functions of the bcXML Browser enables a user to search for objects or catalogue items that are defined in the taxonomy hierarchy. Figure 12 shows the results of a Taxonomy search for a “Timber Flush Door”. The properties that are related to the door are displayed along with their associated units and contexts. The context of a property can be important, for example for the fire resistance of a door as different fire tests can be carried out in individual countries. In this case a 1 hour rated door in the UK will have a BWF Certifire “FD60” rating and in Holland a 60 minute rating according to NEN 6069. This is done in bcXML using the optional “context” attribute that can be associated with “Property” tag as shown in Figure 11.

```
<SolidTimberFlushDoor name="2">
        <fireResistanceRelatedToSeparationFunction context="BWF CERTIFIRE">
           <SingleValue>FD30</SingleValue>
        </fireResistanceRelatedToSeparationFunction>
        <fireResistanceRelatedToSeparationFunction unit="minute" context="NEN 6069">
           <SingleValue>30</SingleValue>
        </fireResistanceRelatedToSeparationFunction>
     </SolidTimberFlushDoor>
```

FIG. 11 – Example of a property having 2 contexts in an bcXML compliant catalogue.

Once the requirements for a product have been specified the requirements message can be routed to the appropriate Catalogue Servers. The eConstruct Prototype Demonstration site can support access to multiple catalogue servers that can be located, both internally on a company’s Intranet and externally via the Internet. Once the Catalogue Server has searched for possible product solutions that meet the specification defined by the bcXML requirements message, the results are presented within the bcXML Browser as shown in Figures 12 and 13.


http://econstruction.citg.tudelft.nl/taxonomyserver/servlet/tax?item2BSearched=SolidTimberFlu...
File Edit View Favorites Tools Help
Back Search Favorites History
Address http://econstruction.citg.tudelft.nl/taxonomyserver/servlet/tax?item2BSearched=SolidTimberFlushD
Go
Links Customize Links Free Hotmail Windows RealPlayer
Done
Internet

Welcome to the eConstruct Prototype Demonstration Site

english version
nederlandse versie
deutsche version
greek version
french version
norwegian version

Search for a name again

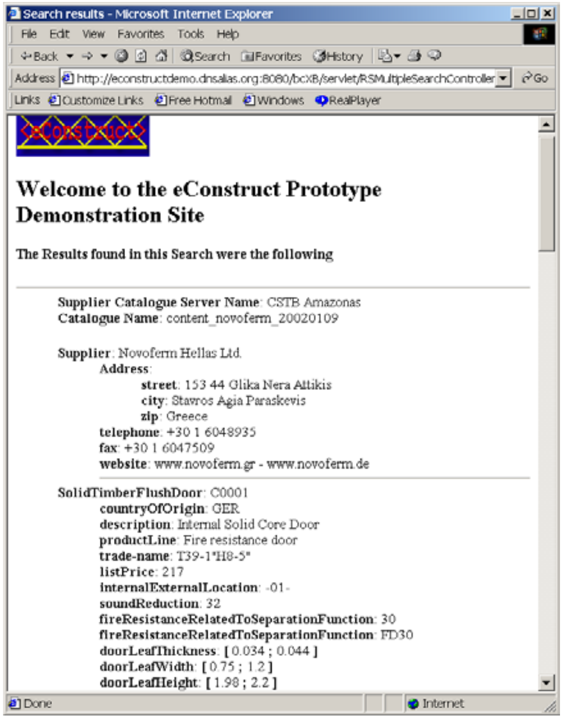
hierarchy

Go one level up to timber flush door

- solid timber flush door

solid timber flush door

Property	Value	Unit
country of origin		
availability		
delivery time		day
catalogue code		
european article number		
description		
product line		
short name		
trade-name		


Search results - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites History
Address http://econstructdemo.dnsalias.org:8080/bcXB/servlet/RSMultipleSearchController
Go
Links Customize Links Free Hotmail Windows RealPlayer
Done
Internet

Welcome to the eConstruct Prototype Demonstration Site

The Results found in this Search were the following

Supplier Catalogue Server Name: CSTB Amazonas
Catalogue Name: content_novoferm_20020109

Supplier: Novoferm Hellas Ltd.
Address:
street: 153 44 Glika Nera Attikis
city: Stavros Agia Paraskevis
zip: Greece
telephone: +30 1 6048935
fax: +30 1 6047509
website: www.novoferm.gr - www.novoferm.de

SolidTimberFlushDoor: C0001
countryOfOrigin: GER
description: Internal Solid Core Door
productLine: Fire resistance door
trade-name: T39-1"H8-5"
listPrice: 217
internalExternalLocation: -01-
soundReduction: 32
fireResistanceRelatedToSeparationFunction: 30
fireResistanceRelatedToSeparationFunction: FD30
doorLeafThickness: [0.034 ; 0.044]
doorLeafWidth: [0.75 ; 1.2]
doorLeafHeight: [1.98 ; 2.2]

FIG. 12: Properties of a Door generated by the TS.

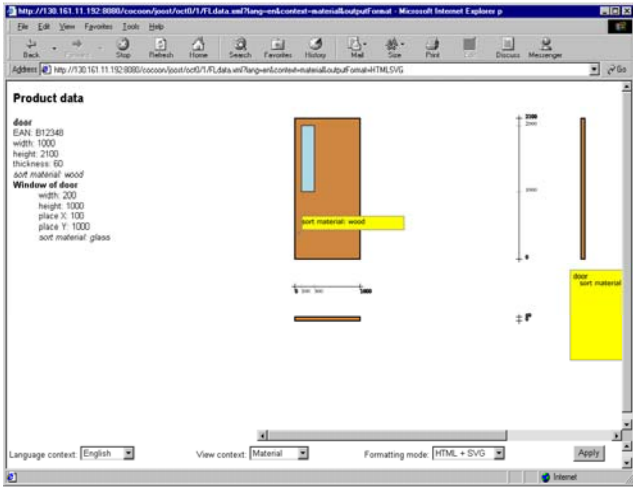
FIG. 13: Possible door solutions.

5.2 Virtual Reality Front-end

The Virtual Reality (VR) Front-end is used to present more sophisticated images of the products being offered by suppliers (Figures 14 and 15). The development of the VR Front-end has investigated how bcXML can be enhanced by multi-media extensions like graphics using SVG and X3D (VRML).

Two applications were implemented, namely the *Multimedia component information front-end* and the *Multimedia project information front-end*.

The first application supports buying and selling scenario and focus on the co-operative design of wall with a door, window, light switch and electricity plug. This type of design always involves people from different disciplines and is rather typical for a broad class of BC design/engineering problems.

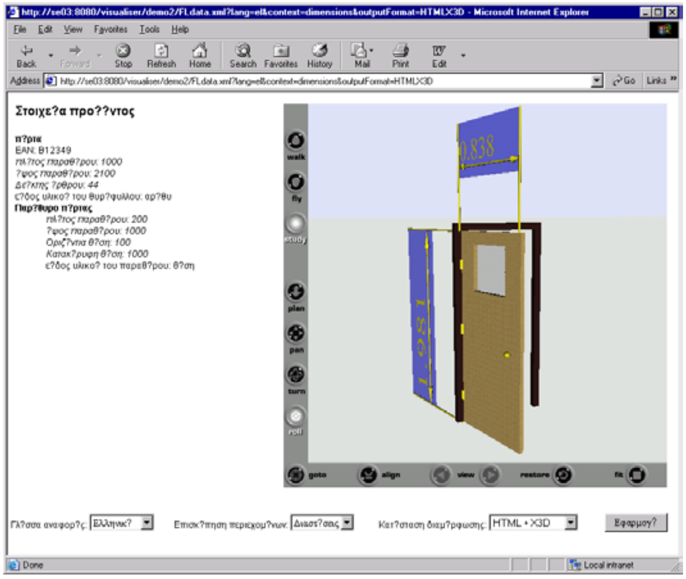

http://130.161.11.192:8080/cocoon/joost/oct0/1/FLdata.xml?lang=en&context=material&outputFormat - Microsoft Internet Explorer p
File Edit View Favorites Tools Help
Back Stop Refresh Home Search Favorites History Mail Size Print Discuss Messenger
Address http://130.161.11.192:8080/cocoon/joost/oct0/1/FLdata.xml?lang=en&context=material&outputFormat=HTMLSVG
Go
sort material: wood
door
sort material
Apply
Internet

Product data

door
EAN: B12348
width: 1000
height: 2100
thickness: 60
sort material: wood
Window of door
width: 200
height: 1000
place X: 100
place Y: 1000
sort material: glass

Language context: English
View context: Material
Formatting mode: HTML + SVG

FIG. 14: Multimedia Component accessing Material information.


http://se03:8080/visualiser/demo2/FL.data.xml?lang=el&context=dimensions&outputFormat=HTMLX3D - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Forward Stop Refresh Home Search Favorites History Mail Print Edit
Address http://se03:8080/visualiser/demo2/FL.data.xml?lang=el&context=dimensions&outputFormat=HTMLX3D
Go Links
walk
fly
study
plan
pan
turn
roll
goto
align
view
restore
fit
0.838
Done
Local intranet

Στοιχε?α προ??ντος

π?ρτα
EAN: B12349
πλ?τος παραθ?ρου: 1000
?ψος παραθ?ρου: 2100
Δε?κτης ?ρθρου: 44
ε?δος υλικο? του θυρ?φυλλου: αρ?θυ
Παρ?θυρο π?ρτας
πλ?τος παραθ?ρου: 200
?ψος παραθ?ρου: 1000
Οριζ?ντια θ?ση: 100
Κατακ?ρυφη θ?ση: 1000
ε?δος υλικο? του παραθ?ρου: θ?ση

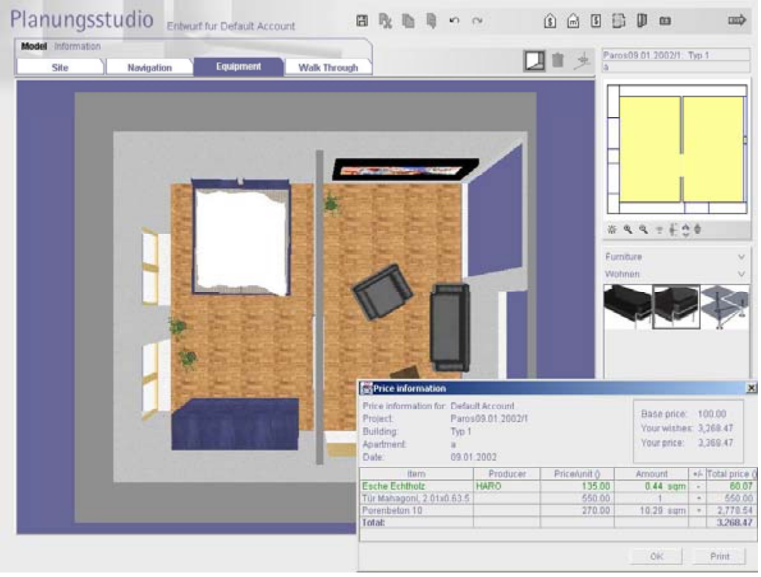
Γλ?σσα αναφορ?ς: Ελληνικ?
Επισκ?πηση περιεχομ?νων: Διαστ?σεις
Κατ?σταση διαμ?ρφωσης: HTML + X3D
Εφαρμογ?

FIG. 15: Multimedia Component displaying Door dimensions in a 3-D view using the Greek language.

The multimedia front-end enables users to access bcXML information in different contexts and views, for example text, 2D or 3D. The context can influence the data used as well as the form such data will be presented. The added value provided by this application is that it can display the data together with a 2D or 3D visualisation of the product. Taking advantage of the multi-lingual feature from bcXML, the information can be presented on demand in a number of different languages, as shown in Figure 15 where the textual information related to the door is presented in Greek.

5.3 Computer Aided Selling Application

The Computer Aided Selling (CAS) system supports the sales process of real estate (apartments and houses) to the clients. The CAS system allows the sales people to present the objects to be sold to their customers in an attractive manner based on always up-to-date product and catalogue data. Figure 16 shows the CAS user interface.



Price information

Price information for: Default Account
Project: Paros09.01.2002/1
Building: Typ 1
Apartment: a
Date: 09.01.2002

Base price: 100.00
Your wishes: 3,268.47
Your price: 3,368.47

Item	Producer	Price/unit ()	Amount	+/-	Total price (
Esche Echtholz	HARO	135.00	0.44 sqm	-	60.07
Tür Mahagoni, 2.01x0.63.5		550.00	1	+	550.00
Porenbeton 10		270.00	10.29 sqm	+	2,778.54
Total:					3,268.47

FIG. 16: CAS User Interface.

The purpose of the CAS client application in the scope of the eConstruct project was to verify and demonstrate the advantages coming from the use of the bcXML technology in the scenario for a sales oriented application for the building industry. The vendor uses the products from the supplier catalogues in order to offer to his/her clients different alternatives of apartments, for instance in terms of material used, final price, and so on. The catalogues can be consulted during the sales process according to the client requirements, which enriches the process.

6. ANALYSIS OF THE SUCCESS OF BCXML

Results from the eConstruct project, including the bcXML language, the bcBuildingDefinition taxonomy, and the bcXML Prototype were presented in a workshop in Delft in January 2002. It demonstrated how the bcXML language can support Building and Construction industry in the procurement of products, components, and services. The project has subsequently created a CDROM that contains the project results and all the software that is needed to install the prototype demonstration that was presented at the final review workshop.

Over the past 12 months about 80 CDROM's have been requested and the feedback has been encouraging, with a number of organisations using the results from the project following successful deployment of the bcXML prototype demonstration.

It is worth noticing that in order to fully exploit the work that has been done so far by the eConstruct project, further work is still needed. There is a requirement for European consensus before bcXML can be fully exploited commercially by the Building and Construction industry. The first step toward bcXML being adopted by the Building and Construction industry is to ensure that bcXML is moved towards standardisation. The first steps for this standardisation process are being done via CEN in collaboration a CEN/ISSS[5] Workshop project called 'eConstruction'.

Another way to analyse the success of a research project is to see how some of the projects results are re-used and further developed by other projects. One such example is the use being made in the e-COGNOS project that has used bcXML as the basis for developing an ontology to support the information related to the Building and Construction industry.

7. THE BCXML IN E-COGNOS

As previously mentioned, bcXML was the format adopted in e-COGNOS to help to quickly and consistently grow the e-COGNOS ontology. Such an ontology has been built aiming at a single goal: to support the consistent knowledge representation of knowledge items in Construction. Two concepts are fundamental in e-CKMI: *Knowledge Items* (KI) and *Knowledge Representations* (KR). The former are the real pieces of knowledge (documents, experts, projects, organisations, etc.) and the latter are the respective representation of KIs within e-CKMI (Lima et al., 2002a).

The e-CKMI is composed of a set of KM Core Services representing its vital functionalities. The KM core services were designed to cover the "classical" functionalities of the KM cycle, such as acquisition, indexing, searching, and dissemination. In this context, the Ontological Service (including the e-COGNOS Ontology and the e-COGNOS Ontology Server – e-COSer) provides the ontology-related functionalities supporting the operation of other core services. Shortly, e-COSer helps preparing the semantically rich indexes to index/retrieve knowledge representations stored in e-CKMI (Lima et al., 2002b).

The taxonomy is the backbone within the e-COGNOS ontology. This taxonomy was created taking the IFC objects as the initial concepts. After it was enriched with concepts coming from different sources (IFC, BS6100, etc.). The addition of attributes and relations have followed the process. However, in nine months of work the ontology had only 800 concepts and one of the fundamental questions to be answered was raised: how to grow the ontology? Considering a well-structured ontology, bigger means the richer. BcXML was the answer that was found. The e-COSer offers a mechanism to import bcXML-compliant taxonomies, which meant that instantaneously the e-COGNOS ontology has growth from 900 to 13000 concepts.

The goal of e-COGNOS is to extend its ontology in a rich way importing well-known taxonomies. However, the effort required to built a bcXML taxonomy is a small one and any very specific taxonomy (e.g., used by one single company) can be imported within the ontology in a very elegant and quick, with no harm at all to the existing ontology. This provides a very accurate level of customisation of the ontology in the sense that there is

[5] CEN/ISSS – Comité Européen de Normalisation / Information Society Standardisation System.

always an open door supporting the aggregation of very local "dialects".

This mechanism is also being exploited in a transcontinental cooperation involving CSTB and the University of Toronto (Lima et al., 2003a). The e-COGNOS ontology will be enriched with the appropriate knowledge about highways and the financial-related aspects of construction projects.

8. CONCLUSIONS AND FUTURE WORK

The eConstruct results, including the bcXML language, the bcBuildingDefinition taxonomy, and the bcXML Prototype were presented in a workshop in Delft in January 2002. It demonstrated how the bcXML language can support Building and Construction industry in the procurement of products, components, and services. The prototype used real catalogues provided by Taylor Woodrow Construction, the British end user in eConstruct. These catalogues were created using Excel spreadsheets and converted into bcXML compliant catalogues, that were registered into two different SCSs managed by the RS. The TS supported the creation of the appropriate bcXML queries and the client applications (bcXB, CAS system, IfcBrowser, and ProjectDB) were able to search and find products in the referred catalogues.

It is worth noticing that in order to fully exploit the work that has been done so far by the eConstruct project, further development work is still needed. Even though the very good results produced in e-COGNOS by adopting bcXML as "source of inspiration" and vital component of the e-COGNOS ontology, the real exploitation of bcXML requires European consensus before it can be fully exploited commercially by the Building and Construction industry. The first steps for this standardisation process are being done via CEN in collaboration with a CEN/ISSS[6] Workshop project called ‘eConstruction’.

The most important work that still needs to be done is the extension of the LexiCon taxonomy. This work is likely to take upwards of 50 man-years and will need to be done by many parties that will include product suppliers and construction product or supplier associations. The resulting LexiCon taxonomy must then be standardised via the relevant standardisation bodies. The long-term goal is to extend the *bcBuildingDefinitions* to become *the LexiCon* taxonomy. Indeed, the eConstruct approach including the XTD and Taxonomy specifications will be taken further and consolidated in planned IST Roadmaps & 6th Framework Programme Integrated Projects, CEN/ISSS standardisation and several national programmes dealing with any form of e-Business or e-Construction.

Additionally, eConstruct project is affiliated to the ICCI IST project, which is devoted to harmonise the work and disseminate the results provided by the IST projects related to ICT in the BC domain. We hope that bcXML can be properly publicized and disseminated among the R&D projects dealing with similar problems, which can catalyse and promote the bcXML journey towards standardization in Europe.

Copies of the bcXML Prototype Demonstration CDROM are available form the eConstruct web site at: http://www.bcxml.org/6-Public/bcXML_CD/orderform.html and project results can also be accessed on line at: http://www.bcxml.org/6-Public/bcXML_CD/index.html

9. ACKNOWLEDGEMENTS

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