Product Libraries – Technology Review

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ABSTRACT: This paper reviews the development of the standards for access to external product libraries in relation to procurement and product data exchange. Procurement accounts for 70-85 % of the value of a building project and hence it is vitally important for the data exchange required to support these processes to be streamlined. Product data exchange between applications is equally important for streamlining the specification, design and construction and maintenance of a building facility. A considerable amount of effort within the Architecture/Engineering/Construction and Facilities Management (A/E/C/FM) has gone into developing standards for product data exchange. Manufacturers and suppliers have supported the development of procurement related standards. With the developments in XML-based standards the technology is now available for developing cost-effective solutions that meet the requirements of both procurement and product data exchange. The paper evaluates the existing and emerging standards and discusses the issues arising from the development of standards for access to product libraries and possible ways forward.

1 INTRODUCTION

The case for providing electronic access to manufactured products data in a structured way is now well established, both for procurement and product data exchange between applications. A recent survey suggests that 75-85 % of the project cost is attributed to procurement [Clark, et. al 1999]. Product information is available through a number of sources, which includes manufacturers, suppliers, and product information providers. The information is available in a variety of formats ranging from paper-based catalogues and unstructured web pages to structured databases. The problem with the lack of standards is that manufactured product data is not being accessed effectively from within applications.

Within Architecture/Engineering/Construction and Facilities Management (A/E/C/FM), considerable effort has gone into defining standard models for exchanging product data using EXPRESS [ISO 1994], a data definition language. A considerable effort has also gone into developing procurement standards, but these standards have been more widely used in industries such as the manufacturing and process industries. The procurement and product data exchange standards have been developed independently of each other largely because of the different business processes involved.

This paper reviews the data requirements in relation to procurement and product data exchange. It reviews the development of the standards for procurement and model-based product data exchange. The role of XML in the development of these standards is discussed.

2 REQUIREMENTS

2.1 *Procurement related requirements*

The main role of procurement systems is to facilitate the purchase, delivery and installation of products. The requirements of such systems include:

- Product identification i.e. description, classification or functional specification
- Order information
- Negotiation
- Secure financial exchanges
- Contract exchanges
- Tracking of transactions and delivery of products.

Procurement does not require detailed attributes of the products. However attributes in conjunction with classification systems may be required for identification. The rest of the data that is exchanged is related to the procurement financial exchanges and the management of the procurement process.

2.2 *Product Data Exchange Related Requirements*

Product models within A/E/C/FM define the physical and conceptual objects that make up a building or construction project. The role of the product models is to provide standards for the exchange of product data between applications within the construction industry. The model-based exchange is not complete without incorporating products that reside in external product libraries, e.g. manufactured products. The requirements of an external library identified in [Nyambayo et al 2000] include:

- common searches across libraries
- common structures to the library catalogues through classification systems or product data dictionaries for easy access.
- common external library management systems e.g. brokers or data warehouses.
- common interfaces to the project environment e.g. IPDB systems, CAD and analysis tools.

Generally, product data definitions in these models are detailed. The amount of data exchanged is significantly more than in the procurement process.

2.3 *Analysis of Requirements*

The need for searching for libraries is common to both systems. Therefore standard catalogue interfaces are essential for both processes. Detailed attributes are not essential to the procurement process while they are essential for data exchange within the design, construction and facilities management processes. Being able to use common data structures will have a positive impact to the management of whole life cycle cost of a facility.

3 DEVELOPMENTS OF PROCUREMENT RELATED STANDARDS

Procurement has traditionally relied on paper-based exchanges, paper-based catalogues, telephone and Fax. A recent survey suggest that most of the transactions within the construction industry still rely on Telephone and Fax [Clarke et. al. 1999]. However, there is evidence to suggest that this is changing as electronic based technology matures and more people become more confident in the new technology. This section reviews some of the existing and emerging standards for procurement.

3.1 *Electronic Data Interchange (EDI) Standard*

EDI (Electronic Data Interchange Format) emerged as a standard in the early 90s**.** It is a protocol and data format for exchanging (mainly financial) data. EDI provides a data structure and mechanism for exchanging the information over value added networks. EDI transactions are business to business transactions that involve no or little human intervention. Subsets of the UN/EDIFACT standard have been developed specifically for exchanges within the construction industry.

The uptake of EDI has been poor within the construction industry. The barriers to its uptake has been the need for value added networks, which proved to be too expensive for small to medium enterprises involved in the procurement process.

Recent developments have involved taking the EDI structure to the web using XML. It has been noted that a simple conversion of EDI tags to XML would not work without significant changes to the data structure. However some of the basic data structure has been adopted in the XML-based standards under development.

3.2 *XML based catalogue standards*

One of the most significant developments in the electronic technology has been XML. XML (Extensible Markup Language is a subset of SGML. XML is not a data exchange standard, but a transport mechanism. The most significant development has been the development of XML-based catalogue standards and integration frameworks. The catalogue standard provides a framework for defining product catalogues. Examples of these standards are briefly described in this section.

3.2.1 *cXML*

cXML (Commerce Extensible Markup Language) standard defines an XML-based protocol and data format for business-to-business transactions, developed by Ariba [Ariba 1999]. It defines electronic catalogues and uses the Internet to exchange documents such as purchase-orders, contracts. It supports parametric searches across catalogues. This standard is supported by Autodesk, XML.Org and Microsoft through its Biztalk [URL1] framework.

3.2.2 *xCBL*

xCBL (Common Business Library) is a rival protocol and catalogue standard developed by CommerceOne [CommerceOne 2000]. It defines purchase order documents, invoice documents and catalogue content documents. The xCBL is quite similar in structure to the cXML. xCBL is supported by a

number of standards development consortia that include:

- RosettaNet [URL2], a consortium of organizations that include Microsoft, IBM, Hewlett Packard, Netscape, whose objective is to develop standards for the exchange of electronic catalogues.
- XML.Org [URL3], a repository for XML schemas that can be used by participating organizations within the same industry to exchange XML based schemas. It is supported by OASIS, a non-profit organization whose objective is to develop and promote the use of XML based standards within and across industries.
- CommerceNet [URL4], a consortium whose objective is to develop XML standards for e-commerce within the financial sector.

Even though cXML and xCBL standards are similar, and have support of common influential industry players such as Microsoft, there is no sign that they will merge.

3.3 *ProCat-Gen Catalogues (Genial)*

PROCAT-GEN [Cook et. al 1999] is an XML based catalogue system for use within the Global Engineering Network. It is the result of an EU funded project. The catalogue system defines a hierarchical classification structure for construction products and product families. Its structure is more specific to the engineering product data than the xCBL and cXML. It provides for more intelligent searches and organization of information. Its features include views and profiles. A view is a facility to define different classification structures for different users. The access to the views is controlled by 'access control lists' (ACL). Profiles define different sets of attributes for different users. For example the attributes used by an architect may be different from a services engineer. However PROCAT-GEN catalogue standard is not publicly available.

3.4 *XML Catalogue Standards summary*

The XML-based catalogue standards, in conjunction with other product data access frameworks, have the potential to provide cost-effective solutions for access to external library product data. However, the problem with having with so many standards is that there is no interoperability between them. Both xCBL and cXML standards are supported by the large industry players. PROCAT-GEN is the result of a pilot project and its use is currently confined to the GEN network.

4 CLASSIFICATION STANDARDS

The catalogue standards described in the s*ection 3* only provide a framework for defining catalogues, but not the product families themselves. Classification systems are required to define these structures.

Classification systems in the construction industry define classes of product families. The classification systems have evolved over a long period of time. Several classification systems exist e.g. CI/Sfb, Uniclass, CAWS, EPIC. According to a survey conducted by RIBA [URL5] CI/Sfb is still the most widely used classification system within the United Kingdom. It is a paper based hierarchical classification system of building products. It has been in existence for over 40 years. In this classification system each product family is represented by a code that is made up of letters and numbers. The structure of the code does not lend itself well to electronic use. The Uniclass system evolved from the CI/Sfb, CAWS CESMME3 and EPIC. The Uniclass system [Uniclass 1997] defines a hierarchical product classification, in addition to management entities, facilities, construction, spaces, civil engineering works, work sections etc. Each product or product family is represented by a letter and number, in a way that lends itself to electronic use. EPIC Version 2 [URL6] released in 1999 {is this an official release?} is the most recent classification system. The product specification in EPIC is similar to the construction product classification (Table L) of the Uniclass system. They both lend themselves to electronic use. There are indications that EPIC and Uniclass are moving closer together in the way they classify products. {they are both built according to the ISO generic classification structure specification, which is why they are compatible}

There are also general classification systems such as the Universal Standard Products and Services Classification (UNSPSC) Code [URL7]. It is a hierarchical classification system for products and services for procurement purposes. It is a result of a merger between the United Nations' Common Coding System (UNCCS) and Dun &Bradstreet's Standard Products and Services Classification (SPSC). The significance of this classification system is that it is supported by VISA and other payment systems. However the classification system is not detailed enough for construction-related products.

The main problem with classification systems is that they are mostly nationally based. The decomposition of products to their constituent components sometimes differ. Some entities defined as products may be elements of larger products in other classification systems. Mapping between these classification system is not an easy task. The only way for-

ward is possibly the de facto dominance of a few classification systems over the rest. {or perhaps efforts like LexiCon?}

5 DEVELOPMENT IN PRODUCT DATA STANDARDS

Product data models within A/E/C/FM define elements used in a building and construction project. A number of models have been developed examples of which include: BCCM [Wix and Liebich 1997], ATLAS [Greening and Edwards. 1995], COMBINE [Augenbroe 1995], RATAS [Bjork 1994], COMBI [Scherer 1995], standards developed by STEP and Industry Foundation Classes (IFCs) developed by the International Alliance for Interoperability (IAI). The role of these models is to provide standards for exchange of product data between applications. These models access external product libraries in different ways. This section reviews the model-based access to external product libraries. The models reviewed in this section are: IFC Release 2.X for the construction industry, Part-lib (ISO 135840) [ISO 1997] for the manufacturing industry and the Epistle Class Libraries for the Oil and Process industries.

5.1 *Referencing External Libraries using Industry Foundation Classes (Release 2.X)*

The Industry Foundation Classes (IFC) model is an integrated model based on ISO 10303 [ISO 1994], representing the physical and conceptual objects used in the A/E/C/FM industry. The model has a number of domains that include Architecture, HVAC, Construction Management, Geometry. A detailed description of the structure of the IFC model can be found in [IAI 1999] and the online documentation on [URL8].

While the model defines most of the products explicitly, it does not attempt to explicitly define all the possible attributes. Instead it uses the property definition to extend the explicit classes. The property definition is a meta-model that defines classes that can be associated to the explicit classes at runtime. {the last entity on the diagram isn't formatted well}

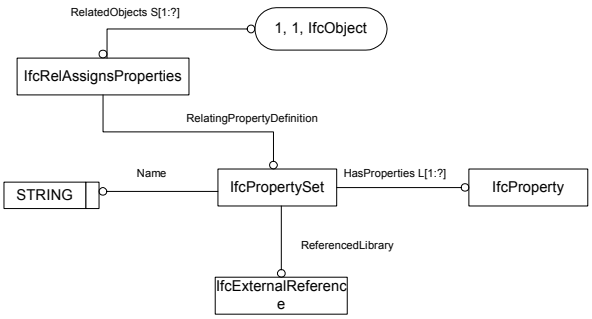

Figure 1: Object extension Model within the IFC Release 2.X (beta) model

Most of the manufactured products are defined as property sets. The extension model is illustrated in the Figure 1.

In this model, the manufactured products (defined as property sets) are related to the explicit classes within the model through a relationship class (*IfcRelAssignsProperties)*. A property set may contain a list of properties. It may also have a reference to an external library, defined in the *IfcExternalReference* schema. The role of the external library reference schema is to capture the information about external libraries. The property set model is described in detail in [IAI 2000]. An example of its use in practice is described in detail in [Nyambayo et al 2000].

PropertySet Definition:

PropertySet Name	Pset_Chair
Typed	True
TypedClass	IfcFurniture
TypeName	Chair
Definition	Definition from IAI: A set of specific properties for furniture type chair. HISTORY: ((existing Pset from IFC Release R1.5)) ISSUE:

Property Definitions:

Name	Property Type	Data Type	Definition
SeatingHeight	IfcSimpleProperty	IfcPositiveLengthMeasure	The value of seating height if the chair height is not adjustable.
HighestSeatingHeight	IfcSimpleProperty	IfcPositiveLengthMeasure	The value of seating height of high level if the chair height is adjustable.
LowestSeatingHeight	IfcSimpleProperty	IfcPositiveLengthMeasure	The value of seating height of low level if the chair height is adjustable.

Figure 2. Sample Property Set describing a chair {this diagram is fuzzy when printed, do you have a clearer version?}

This IFC Release 2.X model supports the use of classification systems. This means that external library information can be organized in hierarchical structures conforming to classification systems such as Uniclass and EPIC. Classification systems can be defined as instances of the *IfcClassificationReference* schema. Furthermore, different classifcation systems can be represented within the model. Products can have a classification system view as well as a model-based view.

The IFC approach does not explicitly define all the product information, but depends on the industry to agree to the structures of their products. The advantage of this approach is that it is flexible. In the construction industry, clients do not have much influence on the procurement process as is the case in the manufacturing and process industries. Supply chains in the construction industry are not estab-

lished on a long term basis. They very much depend on the location of the constructed facility. In such an environment, it is very difficult for the industry to dictate the structures of the product information.

The disadvantage of this approach is that it does not solve the interoperability problem. It passes on the responsibility for standardization to the end users. From an implementation viewpoint, it is not easy for end user applications to manipulate product data effectively if they have no prior knowledge of the structure. For example parametric searches are not easy when the parameters have not been standardized.

5.2 *Other STEP- based Industry Initiatives –The Epistle Class Libraries*

The Epistle Class Libraries provide a standard for defining components used in the Oil and Process Industries. The components defined by this standard are used with the Epistle Core model. The concept of the library is based on STEPLib [ISO TC184/SC4/WG3 1997], a class originally developed for use with the AP221 Step Application protocol within the Process Industry. The components are defied as instances of 'class of object'.

In the Epistle framework, standard components have been defined to form the core of the library. The standard components may be organized in hierarchical classification structures. These classifications could be used to develop manufacturer catalogues.

Unique class id	Subject area	Object type	Class of item name (narrower term)	Association type
100,355	heat transfer	physical object	air conditioner	can be part of a
100,355	heat transfer	physical object	air conditioner	is a class of
100,006	heat transfer	physical object	air cooled heat exchanger	can be part of a
100,006	heat transfer	physical object	air cooled heat exchanger	is a class of
100,380	heat transfer	physical object	air cooled heat exchanger system	is a synonym of
100,006	heat transfer	physical object	air cooler	is a synonym of
100,380	heat transfer	physical object	air cooler system	is a class of

Figure 2. Partial definition of products within the Epistle Class Library

The concept of extending the core model with class libraries is very similar to that of the IFCs where property sets are used to represent the external library products. The main difference is that properties are more closely tied to the objects than is the case in the IFC model. This makes the use of the library, especially the manipulation of the library products by applications, more efficient.

Classification and parametric-based searches can be standardized as all products are predefined. Symbols can be assigned to the classes to enable the use of the product data in CAD and other related applications. A sample of the standard parts defined within the class library are shown in Figure 2

The Epistle approach is very similar to the IFC approach. However in Epistle Class libraries, the products have been defined and structured into agreed classification structures. These classes are related to the rest of the model by the semantic relationships. Access to these classes is as easy as for any other explicit class. This has been made possible by the influence of the large client base within the process and oil industries. The Epistle class library provides for catalogue structures though its classification model.

5.3 *PartLib (ISO 13584).*

Part-Lib (ISO13584) is a STEP standard used for defining external library products, catalogues and the relevant supplier information. The standard represents an integrated approach to the access to external libraries by:

- providing detailed structures of the product data explicitly using its Library_Content schema (13584-24) and Instance schema.
- defining property definitions using the dictionary schema and instance schema. The model explicitly defines parametric parts data.
- defining individual external libraries using the Library Schema.
- defining standards for supplier information.

STEP data exchange protocols such as STEP physical files (Part 21) and Standard Data Access Interface (SDAI) are used to exchange the product data between external libraries and the project environment.

Part-Lib represents an integrated approach to the access to external libraries. It defines all the structures required to access external libraries. This approach works well in the manufacturing industry where clients have more control over the supply chain. In the construction industry the clients do not have the same influence. This is why the models for the construction industry do not try to specify in detail all the attributes.

5.4 *Lessons for the construction Industry*

There are a few things that the construction industry could learn from other industries in terms of developing standards for access to external libraries and these include:

- explicitly defining external library products facilitates the development of applications to handle information in these libraries.
- Defining standards for catalogues facilitates searches across many manufacturer libraries

However there are some inherent problems that are barriers to the development and adoption of these standards, and these include:

- too many regional differences in the way product data is classified i.e. there are too many different classification systems.
- differences in the attribute requirements i.e. between users in the same domain and across the different domains. Therefore predefining these attributes as in Epistle and Part-Lib is a challenge.

6 PRODUCT DATA MODEL RELATED FRAMEWORKS

There are a number of frameworks that have been developed to access externally defined data within the construction industry. Unlike the manufacturing and process industries, where systems based on Partlib and STEPlib are available commercially, the systems available are still largely research prototypes. The lack of progress within the industry is related to the poor adoption of integration within the construction industry. Reasons for the slow uptake of data integration within the construction industry have been discussed in detail in [Amor et al 1999]

6.1 *The ARROW System*

ARROW [Newnham et al 1997] is a manufactured product warehouse that provides access to product information. The ARROW model is an extension of the IFC model release1.5.1 that represents all product information as explicit classes. The model defines attributes for each of the products explicitly. The advantage of this approach is that explicit classes are more efficient to search against. The problem with this approach is that it is not entirely standards-based, as the explicit extensions to the IFC model do not conform to the IFC standard. There are no standards that define all the attributes for products within the construction industry. ARROW demonstrates the need for such standards. The practical application of such a system in the absence of detailed attribute standards is not yet realizable.

6.2 *The CONNET System*

The CONNET system [Amor et al 2000], the product of an EU project, is a service portal that provides access a number of services for the construction industry. The services currently supported are: a construction industry-specific bookshop, news service, product information service, a waste exchange service, a calculation software service and a best practice service.

CONNET has introduced a new dimension to the to the access of information within the construction industry, i.e. the concept of a network of services that provide standard access to information across regional borders. The major advantage of the CONNET approach is that there is standardization in the searches across different countries and a query to one system can be passed on to others.

The barrier to this approach is the different classification systems that are used in different countries. Mapping between different classification systems is still a major issue. Furthermore CONNET does not support the exchange of data between the system and the project environment.

6.3 *IAI UK/BRE External Library Access System*

The Library demonstrator [Nyambayo et al 2000] is a framework to demonstrate the use of the IFC model Release 2.0 and 2.X in accessing externally defined product data. The project is funded by the Department for Environment, Transport and Regions (DETR) in the United Kingdom. The library access system demonstrated the following:

- use of the property sets to structure external product data.
- how parametric searches on products structured as property sets could be implemented.
- how the library model could be used to represent external libraries, i.e. manufacturer or supplier libraries.
- an overall framework for the access of externally defined products, and how these could be integrated into the design environment

The emphasis of this framework, unlike the ARROW system or the CONNET system emphasized the exchange of product data between libraries and the project environment. In the view of the authors, a combination of CONNET-like services and the External Library Access-like systems is the way forward.

7 LINKING MODEL-BASED PRODUCT DATA STRUCTURES TO XML-BASED CATALOGUES –(EXPRESS TO XML MAPPING)

XML is a character-based syntax for representing structured data objects. It is just a serialisation syntax which means that there is still need to develop standards in order to meaningfully exchange any information. Product data structures already exist in EXPRESS format while catalogue standards exist in XML format. The challenge has been mapping EXPRESS data structures to XML.

The problem with XML is that there are many ways of representing an entity, resulting in many possible ways of mapping EXPRESS to XML. This section reviews the standards for mapping EXPRESS to XML that have and are currently being developed.

7.1 *Product Data Markup Language (PDML)*

The PDML [Shocklee et. al. 1999] has been developed by Product Data Technologies and funded by the US Air Force. It is an early binding to EXPRESS. An early bound XML schema or DTD is specific to the corresponding EXPRESS schema. In early binding, the applications developed to manipulate the XML schema have to have prior knowledge of the schema. And these applications can only be used with that schema.

7.2 *XML Meta-data Interchange (XMI)*

XML Meta-data Interchange (XMI) is a specification for defining XML meta-models. It is a specification developed by the Object Management Group (OMG). A meta-model is a generic model for defining specific models. The mapping provided for by this specification is general and can be used with any model including EXPRESS. However, since it was specifically designed for interchange of UML models, it depends on an UML-to-EXPRESS mapping.

7.3 *Part 28 (ISO 10303-28)*

ISO 10303-Part 28 is an ongoing development by ISO/TC 184/SC4. It defines a late binding to EXPRESS i.e. it specifies an XML DTD that can be used to encode one or more EXPRESS schemas and associated data sets. The benefits of late binding over early binding is that applications can be developed to handle any number of schemas and corresponding data sets.

8 WAY FORWARD

The development of the standards for mapping XML to EXPRESS has opened up the real opportunities in the standardization of access to externally defined products. The links between XML-based catalogues and EXPRESS product data repositories is now a possibility.

XML represents a cost effective way of exchanging information and enables elemental data to be exchanged, unlike the case with Part 21 files. There are several possible building blocks to this solution and these include:

- Repositories for the product data schemas, to facilitate the standard specifications of these standards. Existing repositories such XML.org, Biztalk could be used or more specific ones could be developed for use within the construction industry.
- Brokers or Access frameworks, these will provide standard access and querying mechanism for accessing the external catalogues (see Section 6)
- Standard specifications and classifications of the product data. This is probably the area where the product data standards that have been developed in EXPRESS could be used. By applying the mapping between EXPRESS and XML, XML schemas of the product data could be generated. However, within the construction industry the barriers discussed in Section 5.4 have to be overcome.

9 CONCLUSIONS

This paper presented a review of the data requirements and the development of standards for access to external libraries, for procurement and product data exchange in the construction industry. There are similarities in these requirements and there is scope for a common data structure that meets the requirements of both processes. XML-based catalogue standards and XML to EXPRESS mapping are providing a basis for the development of cost-effective frameworks for the access of external libraries.

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