SEVENTH FRAMEWORK PROGRAMME OF THE EUROPEAN COMMUNITY
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INTELLIGENT SERVICES FOR ENERGY-EFFICIENT DESIGN AND LIFE CYCLE SIMULATION

Deliverable D4.3:

Intelligent services for model-based product catalogue profiling and BIM integration

Responsible Authors:

Byron Protopsaltis

Co-Authors:

Thrasos Rekouniotis, Miha Kavčič

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SOFiSTiK Hellas S.A. (SOF)

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Dissemination Level		
PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
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Executive Summary

Deliverable D4.3 comprises the software prototype and this supporting report covering the work done in WP4 "Energy Profile and Consumption Patterns for Built Facilities and Their Components" within **Task T4.3 "Intelligent services for model-based product catalogue profiling and BIM integration"**.

The **objective** of this task is to:

- provide Intelligent services for model-based product catalogue profiling
- extent BIM with product catalog data (focused on the issues addressed in ISES)
- implementation of interface between product representation standards from ISO 10303 STEP and ISO 13584 (PLIB)

The work on the task is performed by the following **partners**:

- SOF - overall concept, implementation, reporting, deliverable lead
- TRI - overall concept, user requirements, data input, catalogue data
- LAP - user requirements, BIM
- NMI - concept
- TUD-CIB - project coordination, report editing, BIM

More comprehensive treatment of building components will be provided in **WP11** added to the original RTD work plan through the merging of ISES with the ISES-enlarged project. This WP extends the work presented herein by developing an ontology for energy aware prefabricated building element representation and intelligent services for element selection, instantiation, consistency checking and configuration built upon it.

1. Introduction

1.1 Purpose of this document

The purpose of this document is to:

- provide a description of the Product Libraries Standard ISO 13584 (PLIB) aligned to the objectives of ISES
- show the way to transfer Façade Element Data and their Technical Specification to a Product Library according to ISO 13584

1.2 Component Manufacturer Collaboration in the Building Industry

The Building Industry is a highly collaborative and specialized industry, and in a building hundreds and thousands of components are being installed. With the intense market competition, the demand for components in the construction industry makes global purchase and modularized supplying necessary.

In order to meet this demand, component manufacturers must work together effectively with their customers and other manufacturers in order to keep the market open for their products.

In the context of the building energy domain the use of appropriate components is especially important because of the high influence both on design decisions by architects and MEP specialists and on the latter energy performance of a building the choice of such components has. In this regard, an issue explored by ISES is the use of pre-fabricated façade elements on the example of the product catalogue of end-user partner TRIMO. Façades are of particular interest because their energy-related characteristics are of utmost importance to the overall energy performance (considered second in importance among all possible measures) and because they intersect various architectural and economic factors that have to be taken into account already in the early design phases. Moreover, decisions on the appearance of the façade have aesthetic quality and are among the first important decisions taken. Therefore, early cooperation and holistic treatment of energy-related issues are substantial for the achievement of a good and efficient energy-aware design.

2. The PLIB Part Libraries Standard (ISO 13584)

2.1 Overview

For the requirements of ISES, the product library standard ISO 13584 (PLIB) is applied. This standard has been widely used as a reference model for developing standardized property lists (cf. Leukel et al. 2006a, b). Major industry consortia from Mechanical Engineering have incorporated this standard into their specifications for property dictionaries, e.g. DINsml (http://www.dinsml.net).

ISO 13584 (1998-2010) is a series of International Standards for the computer-interpretable representation and exchange of part library data. The objective is to provide a mechanism capable of transferring parts library data, independent of any application which is using a parts library data system (Da Silva & Cutting-Decelle, 2005).

Each International Standard in the ISO 13584 series is published as a separate part. These parts are grouped into the following sets:

1. Conceptual descriptions
2. Logical resources
3. Implementation resources
4. Description methodology
5. Conformance testing
6. View exchange protocol
7. Standardized content

The main **purpose of ISO 13584** is to define the structure of a library system that provides an unambiguous representation and exchange of computer interpretable parts of library information.

The data held in the library are a description that enables the library system to generate various representations of the parts held in the library. The structure is independent of any particular computer system and permits any kind of part representation.

ISO 13584 does not specify the content of a supplier library. The content of a supplier library is the responsibility of the library data supplier. The library management system used in the implementation of the structure defined in ISO 13584, and any interface between this system and a user of the system is the responsibility of the library management system vendor and is not specified in ISO 13584.

2.2 Components of a Library System

The current IFC standard is not sufficient to implement product libraries. It is necessary to manage information about and references to parts or components that constitute products. The ISO 13584 Parts Library (PLIB) standard facilitates unambiguous, application-independent representation and exchange of all technical data about parts. PLIB, like IFC, reuses STEP capabilities including the EXPRESS modelling language (ISO 10303-11), the STEP Physical File format (ISO 10303-21), and the Standard Data Access Interface SDAI (ISO 10303-22, -27, -28).

The components which form a neutral library system may be split into a number of functional areas which are illustrated in the next Fig. 1.

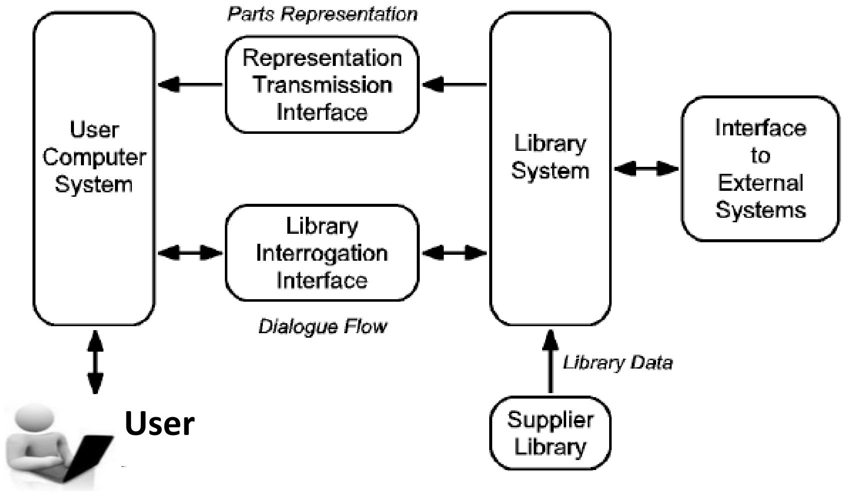


Fig. 1: Functional areas of a library / acc. to Anumba et al. (2007) /

User to computer system communication: The interface between the user and his computer system. This is not defined in ISO 13584; it is application dependent of the user interface as part of an Application system.

Interface to External Systems: The interfaces between a library system according to ISO 13584 and other software systems are:

- *Library Interrogation Interface*: not defined in ISO 13584 provides queries to select parts from the library
- *Representation transmission interface*, enabling the library system to send parts representations to the application / user computer system
- *Input interface for library data*, enabling the integration of supplier libraries within a library system.

2.3 Internal Structure of a Library System

A Library system consists of a Dictionary, a Library Management System and Library Content. The standard defines these modules by the requirements placed upon their functional behaviour. ISO 13584 does not standardise their implementation.

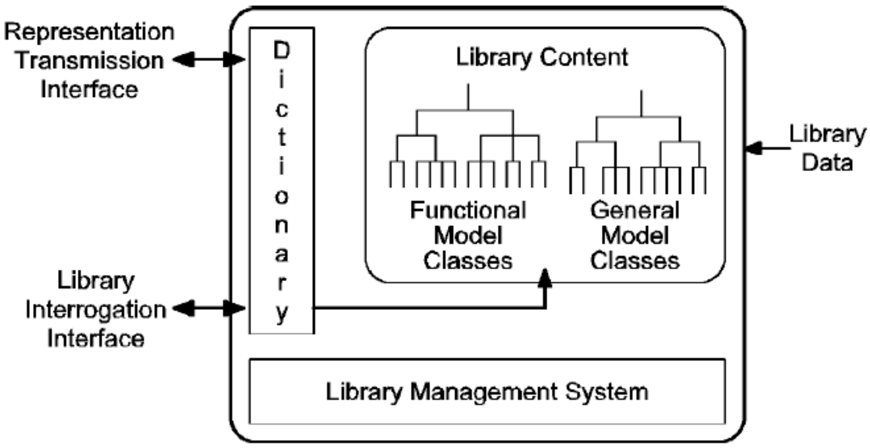


Fig. 2: Library System /acc. to Anumba et al. (2007) /

Dictionary: A set of entries associated with a human-readable and computer sensible representation of the meaning associated with each entry. The dictionary may be accessed by the user and referenced from library data. The Dictionary provides a referencing mechanism between library data obtained from different suppliers and enables the user to obtain an understandable view of the parts held in the library. The dictionary structure is specified in ISO 13584-42 (1998).

According to buildingSMART, a Data Dictionary (bSDD) in its simplest form is a mechanism that allows for creation of multilingual dictionaries or ontologies. It is a reference library intended to support improved interoperability in the building and construction industry, and is one of the core components of the buildingSMART data standards programme.

Library Management System: Software system that enables the end user of the library to use the content of a library and to load data into that library. The Library Management System is not standardised within ISO 13584. It is provided as a Software Tool within ISES.

Library content: Library data are structured into classes (object oriented). Three kinds of classes are considered in ISO 13584. The contents of these three kinds of classes may be exchanged using the structure and exchange format specified in PLIB and they are very important in the Mechanical Engineering Industry.

- *General model classes* enable library data suppliers to provide the definition of a collection of parts considered as a group.
- *Functional model classes* enable library data suppliers to provide various representations (e.g. geometric, schematics, etc.) for these collections of parts.
- *Functional view classes* enable the specification of the kind of representation provided in the different functional model classes. Some functional view classes are standardised in the view exchange protocol series of ISO 13584. A library data supplier may also provide the definition of their own functional view class.

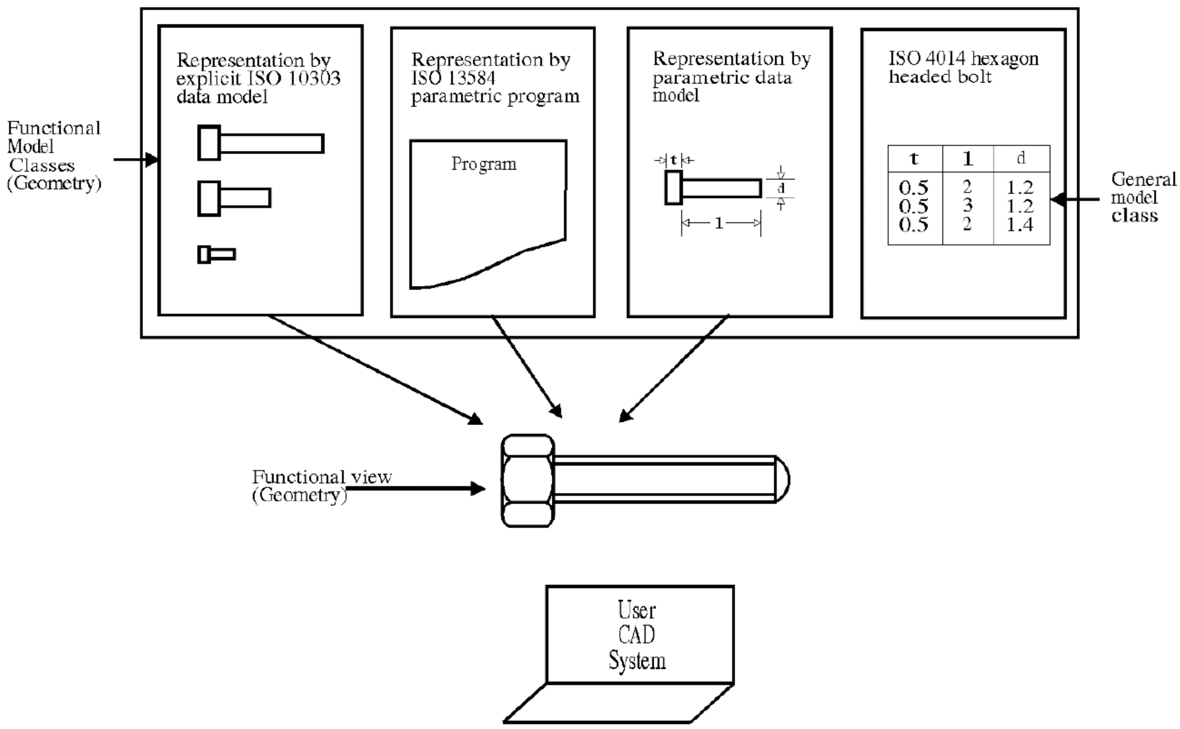


Fig. 3: Structure of library contents /acc. to Anumba et al. (2007) /

2.4 Principles of the Standard

The ISO 13584 standard makes use of a formal data specification language, EXPRESS (ISO 10303-11), to specify information about the structure of a product library. ISO 13584 separates information about the structure of a parts library from the information about different representations of each part or family of parts in the library. ISO 13584 permits information about part representation to be specified by different standards, and includes mechanisms which enable references to such descriptions (Anumba et al. 2007, Elu et al. 1996, Pierra 2003).

2.5 Use of library parts in product data

An ISO 13584 conforming exchange context enables the exchange of library data intended to be stored in a user library. Two principal examples of ISO 10303 STEP and IFC conforming exchange of product data are shown in the next figures, adopted from (Anumba et al. 2007).

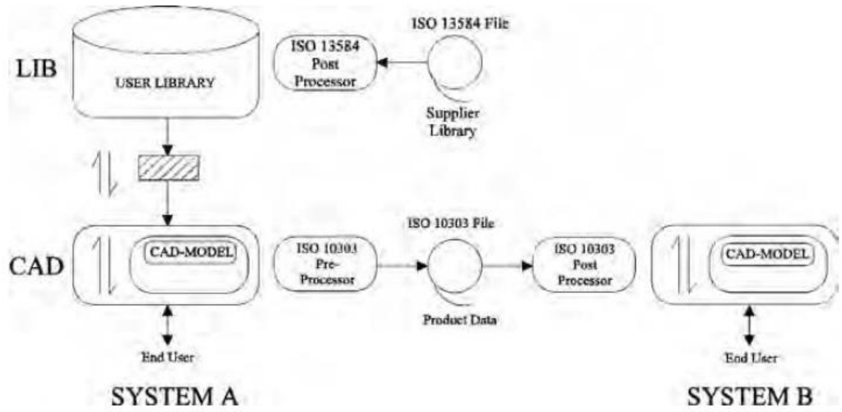


Fig. 4: Typical transfer scenario using STEP ISO 10303

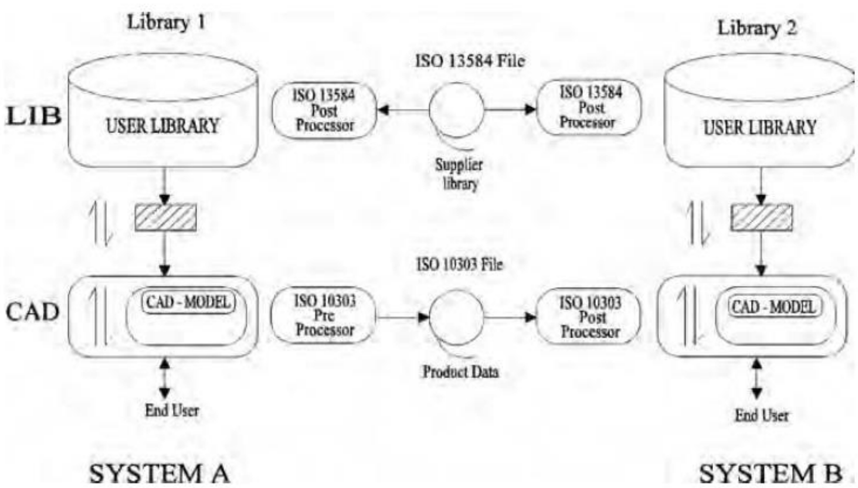


Fig. 5: Specific transfer scenario using PLIB data
(The only information that is transferred from System A to System B is the one necessary to generate the same part from a Library 2 of the receiving System B at the required position and orientation)

3. The PLIB ontology model

According to Bellatreche et al. (2004) and Dinsml (2013), a PLIB ontology model has the following characteristics:

- **Conceptual**: each entity and each property are unique concepts completely defined. The terms (or words) used for describing them are only a part of their formal definitions.
- **Multilingual**: a globally unique identifier (GUID) is assigned to each entity and property of the ontology. Textual aspects of their descriptions can be written in several languages (French, English, Japanese, etc.). The GUID is used to identify exactly one concept (property or entity).
- **Modular**: an ontology can reference another one for importing entities and properties without duplicating them. Thus providing for autonomy of various sources that do reference a shared ontology.
- **Consensual**: The conceptual model of PLIB ontology is based on an international consensus and published as international standards (IEC61630-4:1998, ISO13584-42:1998).
- **Unambiguous**: Contrary to linguistic ontology models (Dinsml 2013), where partially identical concepts are gathered in the same ontology thesaurus with a similarity ratio (affinity), each concept in PLIB has with any other concepts of the ontology well identified and explicit differences. Some of these differences are computer-interpretable and may be used for processing queries, e.g., difference of measure units, difference of evaluation context of a value.

ISO 13584 was originally developed to describe technical product data, i.e. functional and physical characteristics, on the basis of unambiguous, semantically well-defined, globally unique properties. Its usage for commercial product data has been proven as well (Leukel et al. 2006a, b)

To describe how the conceptual model of ISO 13584 has to be implemented, the definition and usage of properties have to be setup.

The goal of defining ISO 13584-compliant properties is to make them available and accessible in standardized online dictionaries. That means that each property:

- is identified with a global identifier which is unique
- is described with a set of mandatory and optional attributes (like for example description, unit, data type)
- is assigned to a set of references to product classes which define context of how the properties can be used;

The number of properties in the dictionary can grow as companies can submit new properties to the standardization procedure to be included in the dictionary. The read access to the online dictionary is free of charge, but companies that want to use it without restriction have to purchase a license. This license includes the passing of the properties used to other companies that are involved in their business process (e.g. suppliers and customers).

When describing products on the basis of properties, it can happen that the property values are dependent on each other.

For instance, if a Panel is described with the property "Thermal Conductivity", this property maybe depends on the temperature or the Thermal Absorption of the Panel.

In ISO 13584 three different types of properties are defined:

- non-dependent properties,
- dependent properties
- conditions.

By deciding to use ISO 13584-compliant properties for storing panel property data, the properties usually do not have to be developed from scratch. The existing data sources (catalogue list) in the information system of TRIMO about panels will be taken into consideration. A methodology for extracting properties from an XML Schema has already been developed (Leukel et al. 2006a, b).

According to the literature, after the required properties are determined, the corresponding properties in the property dictionary have to be found.

Three cases could in general be as follows:

(1) A corresponding property in the dictionary exists and the semantic of the usage is the same. In this case, the property ID from the dictionary and the values from the existing instances can be used without further processing.

(2) A corresponding property in the dictionary exists, but its property definition differs in usage, e.g. about data type or measurement unit. Here, the property ID from the dictionary can be used if the instances can be transformed into the required semantic.

(3) Finally, the company could require properties that have not been defined in the dictionary yet. This is highly dependent on the type of object. In this case, the new property should be created in the dictionary.

4. TRIMO Façade Elements

As an example for creating an EXPRESS data model for building an electronic catalogue, selected products of the ISES end-user partner TRIMO are used (http://www.trimo.eu).

4.1 Pre-fabricated Panel Elements

The **Qbiss One** Catalogue (Qbiss 2011) provides pre-fabricated panel elements consisting of two galvanised and pre-finished steel sheets (internally 0.5 or 0.6 mm thick and externally 0.7 mm thick). The pre-finished steel sheets are bonded to the element core, which is made of non-combustible mineral wool. All three layers make a solid element of thickness ranging 80 – 240 mm.

Fig. 6: Qbiss One elements

4.2 Pre-fabricated Panel Elements Characteristics

CHARACTERISTICS

	Q-80	Q-100	Q-120	Q-133	Q-150	Q-172	Q-200	Q-240
Thickness (mm)	80	100	120	133	150	172	200	240
Weight Qbiss One B (kg/m²)	21.6	24.1	26.5	28.0	30.1	32.8	36.1	40.9
Weight Qbiss One F (kg/m²)	21.4	23.8	26.2	27.7	29.8	32.5	35.8	40.6
U Thermal conductivity (W/m²K)	0.52	0.41	0.34	0.31	0.27	0.24	0.20	0.17
Fire resistance class	/	EI 30	EI 60	EI 60	EI 120	EI 120	EI 120	EI 120
Insulant core	non-combustible mineral wool - density 120 kg/m³, Class A1							
R_w Sound reduction	30 dB ->	31 dB ->						
Length	530 - 6500 mm							
Modular width	600 - 1200 mm							
External profile	G - smooth / 0.7 mm							
Internal profile	g, s, v, v2, m2 - profile / 0.6 mm or 0.5 mm							
External coating	Tata Steel Colorcoat Prisma® - 50 micron pre-finished steel, anti-corrosive and UV protection							
Watertightness	Class B (900 Pa)							

4.3 Data Specification

Technical specification

Qbiss.One

Modular façade system

EN 14509:2006

1404-CPD-1670

Trimo

Characteristic	Test method	Values of individual product thicnesses							
Thickness [mm]	EN 508-1	80	100	120	133	150	172	200	240
Weight - wall panels [kg/m^2][1]	EN 14509:2006	21,6	24,1	26,5	27,7	30,1	32,8	36,1	40,9
Core density [kg/m^3]	EN 1602	120							
Use	EN 14509:2006	External walls, internal walls and ceilings							
Cover width	EN 14509:2006	600 - 1200 mm							
Lenght	EN 508-1	From 0,53 m up to 6,5 m							
External facing	EN 10326	Steel sheet, stainless steel; thicknesses 0.7							
Internal facing	EN 10326	Steel sheet, stainless steel; thicknesses 0.5, 0.55, 0.6, 0.7							
Coating	EN 10169-1	Standard coating PVDF or PUR							
Thermal transmittance U [W/m^{2}K] - wall	EN 14509:2006	0,52	0,41	0,34	0,31	0,27	0,24	0,20	0,17
Thermal transmittance U [W/m^{2}K] - ceiling	EN 14509:2006	0,53	0,41	0,34	0,31	0,27	0,24	0,20	0,17
Reaction to fire	EN 13501-1	A2-s1, d0							
Fire resistance FTV (walls)	EN 13501-2	NPD	EI30	EI60	EI60	EI120	EI120	EI120	EI120
Fire resistance (non-loadbearing ceiling)	EN 13501-2	NPD	NPD	NPD	NPD	NPD	NPD	NPD	NPD
Water permeability	EN 12865	900 Pa (Wall)							
Air permeability [m^3/(m^2*h)]	EN 12114	0,2							
Water vapour permeability	EN 14509:2006	Impermeable							
Airborne sound insulation: R_w (C;C_{tr})	EN ISO 140-3	30(-1;-3)		31(-2;-4)					
Durability - all colors	EN 14509:2006	Pass							

[1] Panels with standard facings 0,7/0,6 mm

NPD No performance determined

4.4 Insulated Facade System

Trimoterm fireproof panels consist of two profiled galvanized (275 g/m2) and painted, steel sheets (0.5 mm - 0.7 mm thick) and insulating non-inflammable lamellate mineral wool core (50-240 mm thick).

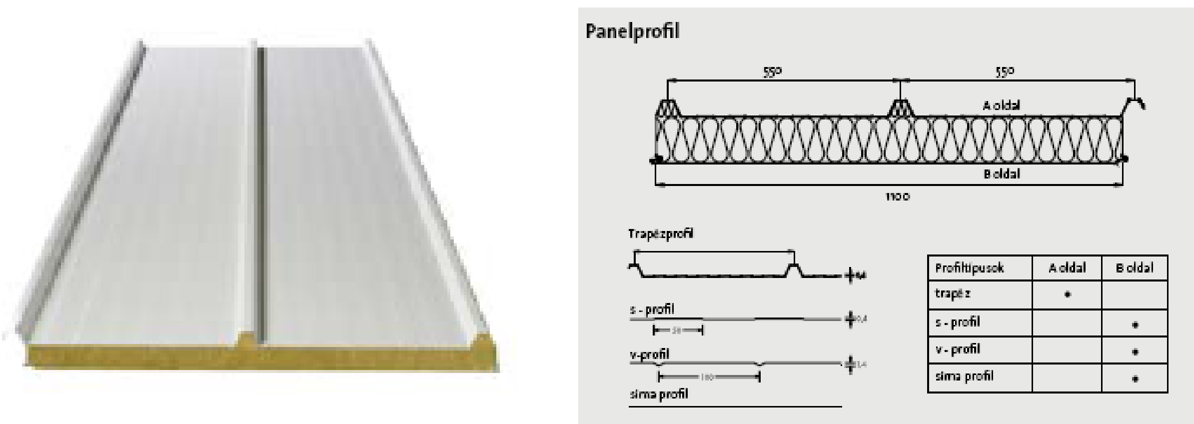


Fig. 7: Trimoterm element

All three layers are bound into a compact, sandwich-type element that provides the required load bearing capacity, tightness and composition. The core, made of non-inflammable lamellate mineral wool, confers excellent thermal and sound insulation, as well as strong fire resistance.

Technical data FTV STANDARD	FTV 50	FTV 60	FTV 80	FTV 100	FTV 120	FTV 133	FTV 150	FTV 172	FTV 200	FTV 240
Panel thickness [mm]	50	60	80	100	120	133	150	172	200	240
Weight FTV 1200 [kg/m²] Fe 0.6/Fe 0.6	16.1	17.3	19.7	22.1	24.5	26.1	28.1	30.8	34.1	38.9
U Thermal conductivity [W/m²K] (EN 14509:2006)	0.74	0.61	0.47	0.39	0.32	0.30	0.26	0.23	0.20	0.17
EI Fire resistance class (EN 13501-2)		EI 30	EI 60	EI 90	EI 120		EI 180		EI 240	
Combustibility of insulant core (EN 13501-1)	Non - combustible, class A1									
Rw Sound reduction [dB] (EN ISO 140-3)		30	32							
Cover width [mm]	1200									
Panel length [m]	up to 14									

5. Implementation

As already detailed, ISO 13584 is a series of International Standards for the computer representation and exchange of parts library data. The objective is to create a mechanism that will be able to transfer parts library data, independent of any application system that is using this data.

5.1 Transformation between XML and EXPRESS Schema

There are two approaches to establish a mapping rule between XML Schema (W3C 2004-2010) and EXPRESS (ISO 10303-11, 2004), i.e. (1) Direct mapping and (2) Meta-level mapping (cf. Kemmerer 2005). Direct mapping represents each entity instance in the PLIB ontology by tag objects in a XML document directly. The meta-level mapping approach consists in redefining the PLIB ontology meta-data, such as it is defined in the EXPRESS model, including the data types, entity declaration, constraints, schema declaration and so on, by a corresponding XML Schema meta model.

5.2 Use of the PLIB ontology

Product data is being created, used, maintained, and exchanged in various business processes that are all part of product data management. So, we will base all product data on a single conceptual model, the PLIB ontology.

There are three different types of properties in PLIB:

- non-dependent properties,
- dependent properties,
- conditions.

For instance, the colour of a Panel Element is not dependent on other properties, whereas other properties like the thermal conductivity may depend on the thickness or the outside temperature. This dependent property is a condition that must be defined. Complex dependent properties usually do not apply to components of the TRIMO products, but it is possible that this will be the case for the next generation of the system.

Additionally to the 'depends_on' relation, it is possible to give a formula defining the value of the respective property by referring to other properties (e.g., area=width*length), like parametric design in a CAD-System. The price of a product, for instance, may depend on a set of multiple factors, such as time and order quantity. For that purpose, PLIB allows only one single relation. Its interpretation is as follows: if a property is defined as dependent from one or many other properties, then the instantiation of this property requires to instantiate the conditions also.

5.3 Commercial product data for business-to-business scenarios

In business-to-business (B2B) scenarios, a great number of XML-based message specifications are available for commercial product data. However, technical product data and commercial product data are being represented in different manner. Therefore, in accordance with the work of Leukel (2006a) an alignment of the representation of technical and commercial views on the product data is proposed. This approach is based on the PLIB ontology, which has been originally described in ISO 13584. The method has been applied to an industrial message specification for electronic catalogues.

According to (Leukel et al. 2006a), a methodology for *ontologising* / restructuring XML schemata that address commercial product data is defined. It performes the conversion of XML schemas of current B2B message specifications into those that adopt the PLIB ontology. Candidates for properties are all elements and XML attributes in the respective commercial product models.

5.3.1 Elements without attributes

Such elements can be directly converted into nondependent properties.

The following schema defines such an element for a product identifier PRODUCT_PANEL which is not deeply nested:

```
<xsd:element name="PRODUCT_PANEL">
  <xsd:simpleType>
    <xsd:restriction base="xsd:string">
      <xsd:maxLength value="14"/>
      <xsd:minLength value="1"/>
    </xsd:restriction>
  </xsd:simpleType>
</xsd:element>
```

The following PLIB-relevant information is extracted:

– property name equals element name;
– data type is mapped to 'string_type' with the PLIB's 'value format' attribute.

5.3.2 Elements with attributes

In XML, attributes can be attached to elements in order to provide additional information on the element and to specify the element content similarly to a type, e.g., the product ID element has an attribute that says whether the ID is that of the supplier, buyer, or a third party:

```
<xsd:element name="Supplier_PRODUCT_ID">
  <xsd:complexType>
    <xsd:simpleContent>
      <xsd:extension base="xsd:string">
        <xsd:attribute name="type" use="required">
          <xsd:simpleType>
            <xsd:restriction base="xsd:string">
              <xsd:minLength value="1"/>
              <xsd:maxLength value="50"/>
            </xsd:restriction>
          </xsd:simpleType>
        </xsd:attribute>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>
</xsd:element>
```

Such attributes require defining a dependent property for the element, and a condition for the attribute, thus the element value can only be interpreted correctly in conjunction with the attribute value. All other PLIB-relevant information on the attribute-derived property can be extracted respectively, but needs to be added manually in the same way as for elements.

5.4 Technical product database

Within ISES, we adapt the approach developed by Tanatsugu et al. (2009), initially suggested in Elu et al. (1996). It provides an ISO 13584 compliant procedure of compiling a 'parts library' for a mechanical element (in our case on the example of Trimo's 'Facades' catalogues).

The intent of intelligent electronic catalogues is to capture and model the knowledge about parts that pre-exist in order to be able to use these parts in any other product.

This methodology proposes to start from paper catalogues that already include most of the knowledge that is to be captured.

The ISO 13584 PLIB standard includes many elements of modern components catalogues, however it is not straightforward to build an EXPRESS data model to represent those catalogues in an automatic way. The persons best suitable to create an electronic catalogue compliant with PLIB are the ones that are familiar with the components that will contain, i.e. the parts suppliers themselves.

The information in a paper catalogue can be inhomogeneous. Some information is easy to model because it is in form of tables, values and units. This can be captured directly in the PLIB presentation. Other information is written in text form that can only understood by a human. To identify and to capture such information a 'manual' methodology is proposed.

Tanatsugu et al. (2009) describe a sophisticated procedure of compiling a PLIB dictionary for a mechanical element by the following steps:

- Create a standardized identification hierarchy by structuring Component families, according to ISO 13584
- Organize all the key information on families and properties into tables like Excel Sheets
- Map the entries in these tables onto instances of the EXPRESS specification, in accordance with STEP (ISO 10303)
- Transform these instances to a STEP physical file, as prescribed in ISO 10303-21 (2002).

5.5 PLIB data model for the TRIMO product catalogues

This section explains how to create an EXPRESS data model representing selected products of the company TRIMO. The presentation as an EXPRESS data model for this particular case is suitable for building an electronic catalogue in an abstract representation since its structure is nearly flat and there are only a few text descriptions needed.

According to ISO 13584 PLIB, a standardized identification of the hierarchy of component parts is described. Hence, the first step of our procedure is to create such a hierarchical family classification for the pre-fabricated "Facade" components.

Table 1. List of classes according to ISO

No.	Class Description
1.	Qbiss One modular façade system
2.	Qbiss Facade Element
3.	Qbiss Corner Element
4.	Qbiss Window
5.	Qbiss Air – Energy efficient glass curtain wall system
6.	Trimoterm Power – Energy and structurally efficient panels
7.	Trimoterm – Insulated façade system
8.	Trimoval – Un-insulated façade systems
9.	Steel Construction

Table 2: List of properties of Facades dealt with in ISO

No.	Name of property
1.	Thickness
2.	Minimum Thickness
3.	Maximum Thickness
4.	Thickness Units
5.	Length
6.	Minimum Length
7.	Maximum Length
8.	Length Units
9.	U Thermal conductivity
10.	Minimum U
11.	Maximum U
12.	U Thermal conductivity Units
13.	Fire resistance class
14.	Water Permeability
15.	Sound Reduction
16.	Combustibility of insulant core
17.	Profile Type (I, IPE …)
18.	Material according to EN S 235 (St. 37-2) or S 355 (St. 52-3)

As a next step, a matrix is defined with rows and columns that correspond to the properties from Table 2 and Table 1.

Table 3: Matrix "properties vs. classes"

Prop. No.	Qbiss Facade Element	Qbiss Corner Element	Qbiss Window	Trimoterm Insulated façade	Steel Construction Element (Profile)
1	x	x	x	x	x
2	x	x	x	x	x
3	x	x	x	x	x
4	x	x	x	x	x
5	x	x	x	x	x
6	x	x	x	x	x
7	x	x	x	x	x
8	x	x	x	x	x
9	x	x	x	x	
10	x	x	x	x	
11	x	x	x	x	
12	x	x	x	x	
13	x	x	x	x	x
14	x	x	x	x	
15				x	
16				x	
17					x
18					x

(Note: Property groups are grouped by aspect via colour codes. Properties 17 and 18 are not relevant for ISES and are only listed for completeness)

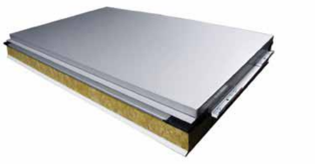
With the help of this matrix, an ISO conforming hierarchy can be created by defining groups and then structuring them respectively.

As already mentioned, PLIB allows only one single relation. Its interpretation is as follows: if a property is defined as dependent from one or many other properties, then the instantiation of this property requires to instantiate the conditions also.

However, if we regard the contents of the above matrix as PLIB-compliant properties and establish the respective 'depends_on' relationships, then we can express the same information in a nested XML structure. Here it must be noticed that for the shown example case and more or less for most of the product libraries in AEC, the resulting XML instances are nearly flat, and not deeply nested. This specific feature considerably simplifies the implementation compared to many mechanical engineering cases.

5.5.1 XML representation for Qbiss Facade Elements

The XML representation of a Qbiss Facade Element, shown in detail in section 4.1, is provided below:



```
<?xml version="1.0"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
<xs:element name="panel">    <-- simplified version -->
  <xs:complexType>
    <xs:sequence>
      <xs:element name="thickness" type="xs:decimal"/>
      <xs:element name="width" type="xs:decimal"/>
      <xs:element name="length" type="xs:decimal"/>
      <xs:element name="weight" type="xs:decimal"/>
      <xs:element name="thermal_conductivity" type="xs:decimal"/>
      <xs:element name="Fire_resistance_class" type="xs:string"/>
      <xs:element name="Sound_reduction" type="xs:decimal"/>
      <xs:element name="External_Profile_thickness" type="xs:decimal"/>
      <xs:element name="Internal_Profile_thickness" type="xs:decimal"/>
      <xs:element name="External_Coating" type="xs:string"/>
      <xs:element name="Water_Permeability" type="xs:string"/>
      <xs:element name="Air_Permeability" type="xs:string"/>
      <xs:element name="Fire_Resistance" type="xs:string"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
<xs:element name="QBISS_FACADE_ELEMENT" type="panel"/>
<xs:element name="QBISS_CORNER_ELEMENT" type="panel"/>
<xs:element name="TRIMOTERM_FACADE_ELEMENT" >
      <xs:complexType>
        <xs:complexContent>
          <xs:extension base="panel">
            <xs:sequence>
            <xs:element name="Combustability_Class" type="xs:string"/>
            </xs:sequence>
          </xs:extension>
        </xs:complexContent>
      </xs:complexType>
</xs:element>
</xs:schema>
```

5.5.2 EXPRESS Schema representation for Qbiss Facade Elements

Below, the EXPRESS Schema for the TRIMO Facade Elements is shown. Since the structure of the XML representation is nearly flat, the EXPRESS Schema can be generated automatically. According to that schema, the transformation to a STEP physical file can also be performed automatically. Hence, both XML-based and STEP-based data exchange can be used for BIM integration on the ISES platform.

```
SCHEMA Trimo_Covering;
  TYPE SIPrefix = ENUMERATION OF  (* corresponds to the IFC def.)
      (EXA, PETA, TERA, GIGA, MEGA, KILO, HECTO, DECA, DECI, CENTI,
       MILLI, MICRO, NANO, PICO, FEMTO, ATTO);
  END_TYPE;
```

```
TYPE SIUnitName = ENUMERATION OF  (* corresponds to the IFC def.)
    (AMPERE, BECQUEREL, CANDELA, COULOMB, CUBIC_METRE, DEGREE_CELSIUS,
     FARAD, GRAM, GRAY, HENRY, HERTZ, JOULE, KELVIN, LUMEN, LUX,
     METRE, MOLE, NEWTON, OHM, PASCAL, RADIAN, SECOND, SIEMENS,
     SIEVERT, SQUARE_METRE, STERADIAN, TESLA, VOLT, WATT, WEBER);
END_TYPE;
ENTITY SIUnit
    Prefix : OPTIONAL SIPrefix;
    Name   : SIUnitName;
END_ENTITY;

ENTITY DerivedUnitElement;
    Unit     : SIUnit;
    Exponent : INTEGER;
END_ENTITY;

ENTITY DerivedUnit;
    Elements : SET [1:?] OF DerivedUnitElement;
    UnitType : DerivedUnitEnum;
    UserDefinedType : OPTIONAL STRING;
 WHERE
 WR1: (SIZEOF (Elements) > 1) OR ((SIZEOF (Elements) = 1)
      AND (Elements[1].Exponent <> 1 ));
 WR2: (UnitType <> DerivedUnitEnum.USERDEFINED)
      OR ((UnitType = DerivedUnitEnum.USERDEFINED)
      AND (EXISTS(SELF.UserDefinedType)));
END_ENTITY;

ENTITY Panel
   thickness: QuantityLength;
   weight   : QuantityWeightPerUnitArea;
   thermal_conductivity       : REAL;
   fire_resistance_class      : STRING;
   Sound_reduction            : OPTIONAL REAL;
   width                      : QuantityLength;
   External_Profile_thickness : QuantityLength;
   Internal_Profile_thickness : QuantityLength;
   External_Coating           : STRING;
   Water_Permeability         : REAL;
   Air_Permeability           : REAL;
   Fire_Resistance            : OPTIONAL STRING;
   length   : QuantityLength;
 WHERE
 WR21: ((SELF.thickness.Unit.Prefix = SIPrefix.MILLI) (* thickness in mm *)
       AND (SELF.thickness.Unit.Name = SIUnitName.METRE));
 WR22: (NOT (EXISTS(SELF.length.Unit.Prefix))         (* length in m *)
           AND (SELF.length.Unit.Name = SIUnitName.METRE));
 WR23: ((SELF.width.Unit.Prefix = SIPrefix.MILLI)     (* width in mm *)
       AND (SELF.width.Unit.Name = SIUnitName.METRE));
 WR24: (SIZEOF (SELF.weight.Unit.Elements) = 2)      (* weight in kg/m^2 *)
       AND (SELF.weight.Unit.Elements[1].Unit.Name=GRAM)
       AND (SELF.weight.Unit.Elements[1].Unit.Prefix=SIPrefix.KILO)
       AND (SELF.weight.Unit.Elements[1].Exponent= 1)
       AND (SELF.weight.Unit.Elements[2].Unit.Name=METRE)
       AND (NOT (EXISTS(SELF.weight.Unit.Elements[2].Unit.Prefix) ))
       AND (SELF.weight.Unit.Elements[1].Exponent= -2));
```

```
   WR25: ((SELF.External_Profile_thickness.Unit.Prefix = SIPrefix.MILLI)
          AND (SELF.External_Profile_thickness.Unit.Name = SIUnitName.METRE));
   WR26: ((SELF.Internal_Profile_thickness.Unit.Prefix = SIPrefix.MILLI)
          AND (SELF.Internal_Profile_thickness.Unit.Name = SIUnitName.METRE));
  END_ENTITY;

  ENTITY QBISS_FACADE_ELEMENT
      SUBTYPE OF (Panel);
  END_ENTITY;

  ENTITY QBISS_CORNER_ELEMENT
      SUBTYPE OF (Panel);
  END_ENTITY;

  ENTITY TRIMOTERM_FACADE_ELEMENT
      SUBTYPE OF (Panel);
      SELF\Panel.Sound_reduction : REAL;
      Combustability_Class : STRING;

  ENTITY QuantityWeightPerUnitArea
      WeightValue          : REAL;
      Unit                 : DerivedUnit;
  END_ENTITY;

  ENTITY QuantityLength
      LengthValue : IfcLengthMeasure;
      Unit :        SIUnit;
  END_ENTITY;

END_SCHEMA;
```

Note that both the XML Schema and the respective EXPRESS schema shown above enable only basic functionality with regard to services for the integration and processing of prefabricated elements like the TRIMO façade system on the ISES VAL. More comprehensive services can be provided by a deeper semantic representation including the taxonomy of elements and their interrelationships, as well as possible parametric variations and the respective rules associated to them. This is part of the work in the new WP11 of ISES, resulting from the updated DoW after merging with the ISES-enlarged project.

6. Conclusions

This document describes the general procedure for compiling a PLIB dictionary for the specific case of prefabricated façade elements of the TRIMO product line. This procedure organizes the groups and properties of the various available products in tables and matrices, with the aim to map them onto XML description and instances of the EXPRESS specification so that they are automatically transformed to an ISO 10303 STEP physical file leading to an intelligent electronic catalogue. This catalogue is integrated on the ISES Virtual Energy Lab (VEL) platform using the framework for the access to energy-related ICT information (Gudnason et al. 2013) and the ISES platform ontology.

The bindings of the catalogue data to the BIM/IFC model is provided by WP3. The implementation of that binding will be provided in the next project phase as part of the work in WP5 and WP11. Moreover, through the work in WP11 the developed basic concept and procedure will be extended to an ontology for building components and intelligent services for their search, selection, retrieval and configuration for simultaneous energy simulation and analysis of various design alternatives,

In this way, two goals are achieved:

(1) Flexible, standardized and product-independent integration of product components in the host product (the building)

(2) Standardized, extensible procedure to use such data in various business workflows in automated manner.

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Appendix I: Acronyms

AEC	Architecture, Engineering and Construction
BIM	Building Information Modelling (Model)
GUID	Globally Unique Identifier
ICT	Information and Communication Technology
IFC	Industry Foundation Classes
PLIB	Product Libraries – ISO 13584
RTD	Research and Technology Development
STEP	Standard for the Exchange of Product model data - ISO 10303
VEL	Virtual Energy Lab
WP	Work Package
XML	Extensible Mark-up Language
XSD	Extensible Mark-up Language Schema Definition