SUSTAINABLE BUILDING RELATED NEW DEMANDS FOR PRODUCT INFORMATION AND PRODUCT MODEL BASED DESIGN

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SUMMARY: *This paper describes and summarises the recent results from studies carried out at VTT concerning the contents of construction product information and its use in different stages of building project and building maintenance from two specific points of view: 1) product model based building, 2) life cycle management of buildings. The objective of the work was to describe and define the contents of building product information needed from the view point of service life and life cycle design and maintenance of buildings considering the latest developments in building product standardisation especially from the European point of view. The paper also drafts alternative information management solutions for the use of this information considering the challenges of product model based building. The paper discusses the contents, transfer and use of construction product information in different stages of building project and building maintenance. The subject is discussed and dealt with based on the premise that sustainable building will significantly increase the needs of product specific information both in building processes as well as during the maintenance of buildings. Design for service life and sustainability requires new information including for example service life information, LCA data and information on harmful chemicals and emissions. Design for service life and sustainability may also require detailed information about technical performance of products. Because of the abundance of the needed information, and the different needs in different stages of building projects, efficient information technological solutions are needed.*

KEYWORDS: *sustainable building, life cycle, product information, product model.*

1. INTRODUCTION

This paper discusses the contents, transfer and use of construction product information in different stages of building project and building maintenance considering the challenges of life cycle management of buildings and product model based building. Chapters 2 and 3 define the objectives and the procedure of work. Chapter 4 introduces backgrounds for the work including a summary of the earlier and corresponding research results and a summary of the standardisation situation. Chapters 5 and 6 formulate the contents and use requirements of product information and give examples for outlining product information. These results are based on the findings of the author in the Finnish research projects. Chapters 7 and 8 finally discuss the findings in relation with the stated background and summarise the paper.

The subject is discussed and dealt with based on the premise that sustainable building will increase the use needs of product specific information both in building processes as well as during the maintenance of buildings. Service life design and design for sustainable and healthy built environment need new type of information including for example service life information, life cycle assessment (LCA) data and information about harmful chemicals and emissions. Design for service life and sustainability may also require detailed information about technical performance of products. ISO TS 21929 (ISO 2006a) defines that sustainable construction brings about the required performance with the least unfavourable environmental impact, while encouraging economic, social and cultural improvement at a local, regional and global level. Because of the abundance of the needed information, and the different needs with regard to this information in different stages of the building project, efficient information technological solutions are needed.

The European Construction Technology Platform (ECTP 2006) has analysed the major challenges that the sector will face in terms of society, sustainability and technological development. Europe has developed research and innovation strategies to meet these challenges and defined key challenges that the European construction technologies have to overcome. These include among others the following goals: to reduce the use of energy, materials, and other resources in construction and in the built environment; to make construction become an advanced knowledge economy sector at all levels of the supply chain. It has been stated by the ECTP (2006) that "Construction materials have an important role to play in sustainable development through their energy performance and durability, as this determines the energy demand of buildings through the lifetime. By developing the use of materials and their combinations, significant improvements of the environment and quality of life can be achieved."; "The essential challenge and expected impact is the development of innovative businesses and application concepts improving existing working processes or leading to new ones, and based on advanced innovative knowledge-based ICT instruments to be introduced in a fully integrated way so as to support these processes."

This paper defines the following terms in accordance with ISO 14040 (1997) and ISO 6707 (2004):

- life cycle:
  consecutive and interlinked stages of a product system, from raw material acquisition or generation of natural resources to final disposal (ISO 14040),
- service life:
  period of time after installation during which a building or its parts meet or exceed the performance requirements. (ISO 6707-1).

The ROADCON project (Hannus et al. 2003) developed a vision for agile, model-based, knowledge driven construction. According to the ROADCON vision "Construction is driven by total product life performance and supported by knowledge-intensive and model-based information and communication technology (ICT) enabling holistic support and decision making throughout the various business processes and the whole product life cycle by all stakeholders."

2. OBJECTIVES

This paper describes and summarises the recent results from studies carried out at VTT concerning the contents of construction product information, its transfer and use in different stages of building project and building maintenance from two specific points of view: 1) product model based building, 2) life cycle management of buildings.

Life cycle management and improved sustainability of buildings will require the development of building product information and its processes of use. It will be necessary to develop the contents and supply of information as well as the models of exchange and use of this information in order to ensure the management of the required building performance and environmental impacts during the life cycle of buildings. The abundance of this information provided by suppliers and manufacturers and the different needs in different stages of the building process requires the development and use of new information technological solutions.

The objective of the work was to describe and define the contents of building product information needed from the view point of life cycle design and maintenance of buildings considering the latest developments in building product standardisation especially from the European point of view and to draft alternative information technological solutions for the use of this information considering the challenges of product model based building.

3. PROCEDURE

The research was carried out analysing building product information contents and information needs in different stages of building project and service life. The analysis was done with help of interviews, discussions and case studies together with representatives from 30 enterprises from the Finnish Architectural, Engineering and Construction (AEC) industry, 4 organisations representing manufacturers and contractors and 1 organisation representing the delivery of building information (Building Information Institute). These enterprises and organisations represented the whole industry in such a way that representatives of product manufacturers (20), designers (6), contractors (7) and owners (1) were involved. In addition, the study was based on literature review concerning building product information management with reference to product models and on the researchers' expertise and knowledge in building product information and its current developments with regard to information contents, presentation and standardisation.

4. BACKGROUND

4.1 Search and exchange of product data

The development of eBusiness aims at improving the information flow and rationalising the selection of services and products in AEC practice. Web-based construction products catalogues, which enable interoperability through Web-services technologies offer efficient models for information sharing (Kong et al. 2004). However, Shaaban et al. (2003) have found out that the user's ability to seek information hinders the potential usefulness of product libraries and catalogues for AEC practice. Zou and Seo (2006) suggest that the reluctance of the subcontractors and suppliers to adopt the technologies and the lack of integrated information management systems retard the implementation of eBusiness. These findings emphasise the need to enhance systems with improved user interfaces enabling the efficient use of product information for various needs in building projects.

As described by stated by Shailesh and Godfried (2003) there are two approaches commonly used for finding products in e-Catalogues 1) descriptive searches which are based on matching text strings and 2) attribute-based searches which are based on matching products. A descriptive search typically produces large sets of product lists. Attribute searches assume that products can be selected on the basis of their attributes. This requires that 1) the user has knowledge of the attributes on which to search, 2) the user is aware of the acceptable range of values for each attribute, 3) the user understands the significance of each attribute in the design. Attribute searches are suitable in the construction phase of project when detailed product specifications are available, but a common understanding on product specifications in the AEC industry is required.

The use needs of product specific information will increase because this information is needed in different kinds of life-cycle design and management of buildings. However, the ideas of eCatalogues do not originally serve the needs of analyses and design, but the needs of product selection. According to Lima et al. (2003) a better integration of the supply chain with the process will improve the use product information. This can be achieved using improved communications that make use of open standards, structured communication between applications, and semantic or object based communication. Lima et al. (2003) introduce the results of the eConstruct IST project, which developed a communication technology called Building and Construction eXtensible mark-up language (bcXML). bcXML was developed to improve the usefulness of product catalogues. Through the bcXML, eConstruct project enabled the creation of requirements messages that can be interpreted by computer applications able to find products that meet those requirements. Kong et al. (2004) propose an interoperable construction products catalogue model, which enables interoperability of Web-based construction products catalogues through Web-services technologies.

Shailesh and Godfried (2003) have analysed search methods dividing those as follows: a) Not-standardisation driven approach: User finds web site either through information broker web site or by conduction a web search using popular search engines; b) Product information standardisation at source side: Product information brokers require independent manufacturer/supplier to provide product information in standardised formats (e.g. bcXML); c) Product information standardisation on broker side: Independent manufacturer/supplier uses information broker to disseminate product information. None of these methodologies allow designers to search for products that are capable to fulfil the required functions. To facilitate such product selection, a performance-based approach is required. In this approach the user first selects the interesting elements. The interface then presents the user the relevant choices of performance indicators; a query in bcXML format is submitted to participating manufacturers; and a bcXML formatted list of products that meet the functional requirements is returned. The approach suggested by Shailesh and Godfried (2003) might be especially suitable for building products that can be dealt with as functional units such as windows or outdoor wall elements. However, the approach is difficult to be applied for other products such as heat insulation products, roofings etc.

Building product manufacturers already provide information that is needed in sustainable building design. This information includes - in addition to information on technical performance - also information on service life and environmental performance. The problem is the access to this information with help of means that support search, transfer and use of data in users own applications. Karstila and Seren (2005) have dealt with data exchange between product libraries and applications. The essential information contents of product libraries include identification, classification, composition and performance. It is notable that product data should be available through the life cycle of the building. The applications using product libraries should be able to communicate; the applications have to be able to define terms for searches, transfer or directly receive data, instance it into the application's own product model; and there should be a common understanding about the classification of products and building parts. When developing solutions, there should be an understanding about the contents of product information and needs of product-specific information in different stages of building process.

The significance of product information increases, because it is needed in service-life design, life-cycle assessments, simulation, requirements verification, formulation of as-built information and within care and maintenance. It is also notable that the contents and type of this data can vary for different product groups. It is not possible for designers or maintenance personnel to define the detailed, product-specific information, but it must be created and provided by manufacturers. Manufacturers have already formulated and published detailed information on technical and environmental performance, but the existing data are not in a coherent and automatically usable format. There is a need to start to produce standards for the content, structure and format of the product information. The format must be computer interpretable, such as ifcXML, and the content must respond to the needs of different situations and analyses tools (Kiviniemi 2005a). One example of the work in this area is LifePlan research project (Häkkinen et al. 2004a), (Häkkinen 2004a). The project introduced methods how to use product-specific service-life information in service-life design and within care and maintenance of buildings. LifePlan project created a framework for a database where manufacturers are able to store all product specific service life information (see section 6.1). Fig. 1 shows the principal solution of the database. Improving the model based building calls for the development of product model libraries covering all adequate parts of the product information needed in the life cycle design and maintenance of buildings. One of the efforts in this area in the near future will be new Industry Foundation Classes (IFC) extension project "Service life planning and durability of buildings and materials" which is related to ISO 15686 standard (2000).

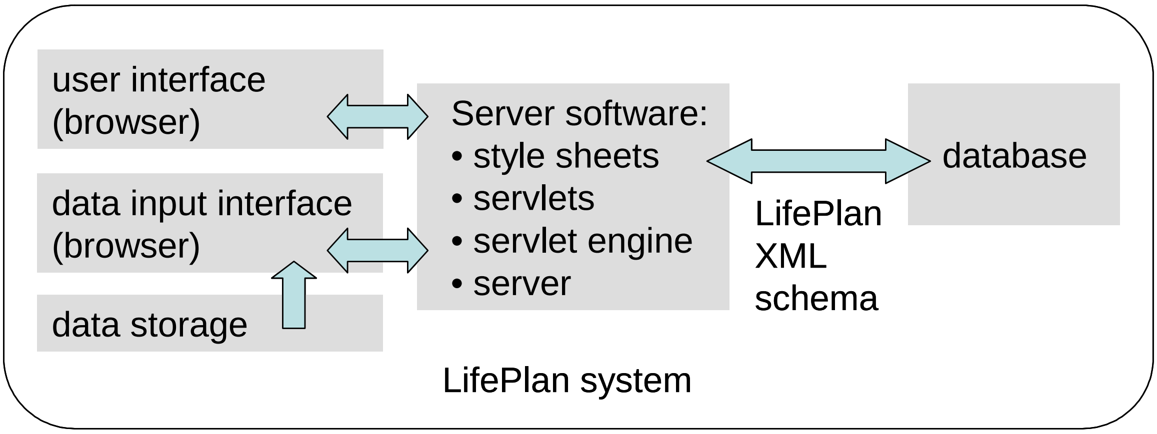

FIG. 1: LifePlan database system. The system is a prototype system for building product data supply and storage.

The modelling of interoperable information in computer-aided architectural design should involve not only the representation of full geometry of building objects, but also all other non-graphical project-related information. In principle, the IFC technology provides mechanisms for the uniform representation and exchange of all project information. It also specifies approaches for extending the IFC object model. Yang (2003) describes a method to develop IFC compliant information for 3D architectural design by the use of the IFC technology and IFC Property set extension mechanism. The property database was composed of XML documents. Each XML file defines one Property set with a collection of properties. Yang (2003) intends to further develop the IFC-compliant information modelling and sharing method for encapsulation of CAD object behaviours and references to external sources of digital product information, such as online libraries of product catalogues, and to share the encapsulated design information with more downstream software applications.

The technical committee ISO TC 59 Subcommittee 13 has developed standards for organization of information about construction works. ISO 12006-2 (ISO 2001a) describes a framework for classification of information. The framework is based on simple process model approach according to which construction resources are used in or required for processes, the output of which are construction results. Resources include construction products, agents and information. Results are construction entities in various stages of life cycle. As defined by ISO 12006-2 elements are construction entity parts, which fulfil a predominating function of the construction entity. Product information is needed in the design, production, use and maintenance and demolition stages of elements in order to design for and maintain the required performance. While the approach of ISO 12006-2 is classification, the approach of ISO/PAS 12006-3 (ISO 2001b) is object oriented: it describes characteristics of things without a grouping preference. Such an approach is also chosen in the ISO 13030 series (Industrial automation systems and integration - Product data representation and exchange). ISO/PAS 12006-3 specifies a language-independent information model, which can be used for the development of vocabularies used in information about construction works. The model helps to define concepts, which are objects defined by properties. Objects and properties can have relationships and those can be grouped. The set of properties associated with an object provide the formal definition of the object as well as its typical behaviour. This paper acknowledges the object oriented approach. This approach will probably support the use of large information entities needed in life-cycle design and management of buildings. The information that is needed in life-cycle design and management of buildings much concerns product information. This paper focuses on the problematics of product information, mainly from the view point of the contents and structure of this information but at the same time considering the challenges that are associated with the exchange of this information in order to support life-cycle design and management of buildings.

4.2 Product models and product information

The Finnish ProIT project (ProIT 2005) described the framework for product model based design, construction and maintenance process. The project studied building projects as examples, which tested potentials of product models with regard to different information management cases. The best experiences were received with bill of quantities and cost accounting. Bill of quantities is an obvious example of potential advantages. Because the current and widely used design software products are already based on product models - although their have their own internal model - and because the representation of geometry of building objects is already included, the inclusion of data that is related to geometrical data is one of the easiest tasks. Correspondingly it should be moderately easy to include LCA based calculations into the product model with help of object technology because environmental impacts are proportional to the quantities of products as well. The so-called environmental profiles of products are lists of emissions and resources consumptions normally given per mass quantities of products.

Product model based design means structuring of product data so that it facilitates identification of information and grouping of information according to different criteria. The product model can in principle be saved as a data base or as data transfer files. According to Niemioja (2005) product model servers will be used to share and deliver information between partners. The information contents of architect design are completed during the design process. Thus product structures related information should also be possible to be completed during the process. In a product model based design process the designer produces a model which defines the design result and which includes the spaces, building parts and the properties of those. The inclusion of product information and product specific requirements to product models is discussed below in this paper (section 7).

Kiviniemi (2005a) discusses the potentials of interoperable product models as ICT platforms to integrate the building design and life-cycle information and to enable testing using virtual buildings as prototypes. One requisite for the computational use of the information is a defined syntax and semantic data structure, such as a product model. Although many of the current design software products are based on such models, these have their own internal model. Development of specifications for international building product model standard is an attempt to improve the situation. The IFC2x Platform specification has been officially accepted as a Publicly Accessible Specification (ISO/PAS 16739:2005) (2005). However, the use of interoperable building product models in real projects has still been very limited. Thus the development of rules for computer interpretable formats is an important R&D objective.

Life cycle assessment, assessment of life cycle costs, service life design and design for care maintenance need product specific information. These assessments and analyses are not and should not be methods, which only aim at verifying the design, but analyses should be carried out for different design options and choices. Thus the question of revision handling is important. Service life and life cycle assessments will probably be done at least partly with help of separate tools instead of being solved "inside" the product models. The development has resulted in an open-source solution available for research and development purposes (Kiviniemi 2005a). Commercial IFC model servers have been started to develop, and the next step in the IFC server development was the development of a standardised API for different model servers.

Suter and Mahdavi (2004) discuss aspects of representation framework and performance-based design. Building representations can be characterised as being either semantic or spatial centred. Most building product data modelling efforts emphasise semantic concepts for spaces, walls, or windows; spatial information is treated as a property of such concepts. Conversely, spatial information plays a central role in drafting and geometry modelling. The authors believe that these issues do not receive sufficient attention in the on-going building product data modelling efforts as in the IFC technology.

According to Kiviniemi (2005b) the instantiated model of a project, i.e. project's data set should be divided into four separate models: Requirement model, design model, production model and maintenance model. The information content in the different design and contractor domains is so different that there is a need for several design and production models. According to Niemioja (2005) the architect's product model may include product specific data, but basically the model is a building part model (as designed). The final up-dating of the product model is done on the basis of construction process (as built). In this model the supplier-specific information are linked with all building parts and equipment.

With regard to product information, it can be outlined that:

- design model should give guidelines and requirements for product selection,
- building model forms a basis for care and maintenance,
- maintenance model gives care and maintenance data in scheduled format and
- all product have be possible to be identified and located in the building.

Kiviniemi (2005b) analyses good solutions for the requirements model. He defines three alternatives to define a requirements model. These are 1) Use of generic requirements objectives; 2) Use of attribute set which contain the requirements and attach them directly to building elements; 3) Use of detailed requirements model specification which specifies the relations between the requirements and building elements. The main problem of the first alternative is that there is indirect linkage between requirements and the design; it is difficult to anticipate all the objects which a requirement potentially affects. The main problem of the second alternative is that the internal structures of design software do not support shared attributes. If requirements are stored in the design model, the same requirements are multiplied in instances, and this causes difficulties when requirements are changed. Requirements should be in separate objects which can be linked to each other in the requirements model and to the related objects in the design, production and maintenance models.

According to this approach the building level requirements are stored in their own instantiated model, and they are linked to the design model. The power of a requirements management system, which would link the requirements to the design models, is largely in making the explicit but "hidden" information visible to the whole team. Kiviniemi defines his requirements model specification formally as an extension of the current IFC specifications. Respectively as separating building level requirements from design model, product level requirements should be stored in the design model and separated from the production model. Product specific information should rather support and guide designers to set requirements for the selection of products during building in order ensure that the designed performance of building parts will be fulfilled. As-built model should finally include all detailed and product specific information on the basis of which the scheduled maintenance of systems can be organised.

4.3 Standardisation of product information - exploitation of standardised formats

Internationally and in Europe there is an intensive standardisation process going on aiming at structuring of the contents of building product information. There is also a process going on which aims at the organization of information about construction works as explained in section 4.1, but this section deals with standardisation from the view point of information contents. ISO TC59/SC 17 (ISO 2006b) has a task of formulating standards concerning environmental assessment, indicators and environmental declarations of building and building products. ISO TC 59/SC 14 (ISO 2006c) has formulated service life planning related standards. The European Construction products directive and related harmonised standards formulate essential requirements and technical specifications for building products. In addition, a standardisation mandate (M/350 EN 2004) has been given to CEN (CEN 2005) to develop horizontal standardised methods for the assessment of the integrated environmental performance of buildings. These standards concern the contents and grouping of building product related information without paying attention to requirements of data representation and data transfer. However, the foreseen situation, in which we have a common understanding about the contents and structure of building product information, will certainly significantly help the possibilities of product libraries and eCatalogues to deliver product information for the needs of building design and selection of products in building process. As described in sections 4.1 and 4.2, many research projects have already introduced information and communication technological solutions alternatives for data search and selection, delivery of information through product libraries, data exchange, and data storage in different models. However, the realisation of these potentials requires a common understanding about the contents of information, for the management of which these systems are planned.

Construction products directive (89/106/EEC) (EEC 1988) is among the European directives which have been adopted on the basis of the New Approach (EC 2006). These aim to create a single European market by removing the technical barriers to trade between Member States through the use of harmonised standards and approvals. Features of this legislative technique include the definition of mandatory essential requirements, the setting up of appropriate conformity assessment procedures and the introduction of CE marking. The European standards bodies have the task of drawing up technical specifications which offer one route to complying with these essential requirements. EC directives define the essential requirements, e.g. concerning protection of health and safety, that goods must meet when they are placed on the market. The European standards bodies have the task of drawing up the corresponding technical specifications meeting the essential requirements of the directives, compliance with which will provide a presumption of conformity with the essential requirements. Such specifications are referred to as "harmonised standards". The European product standards address certain technical properties for different product groups. Harmonised standards are technical specifications adopted by CEN, Cenelec or both, on mandates given by the Commission. According to targets set by CEN and EC, these standards will be formulated for 560 product groups. 2/3rds of the planned standards have been worked out. Standards focus on safety and health aspects and in new standards also durability aspects.

The European harmonised standards adopted by CEN have now been actively worked out for building products. These technical specifications will form a useful basis for product information related requirement setting in design and for search of products during construction. This will at least partly solve the problems stated by Shailes and Godfried (2003) as they discuss about attribute related searches. With help of product standards the user should have knowledge of the attributes on which to search, and the user should also be able find information about the acceptable range of values for each attribute.

The procedure of formulating these specifications aims at ensuring that all essential technical product specific properties are considered with reference to the essential requirements stated in the Construction products directive (Anon 2006c). These essential requirements are as follows: Mechanical resistance and stability, safety in case of fire, hygiene, health and the environment, safety in use protection against noise and energy economy and heat retention. According to the directive, the essential requirements must, subject to normal maintenance, be satisfied for an economically reasonable working life.

In addition, EC/DG Enterprise has given a standardisation mandate (M/350 EN 2004) to CEN to develop horizontal standardised methods for the assessment of the integrated environmental performance of buildings (CEN 2005). The field of the work of CEN/TC 350 is to develop voluntary horizontal standardised methods for the assessment of the environmental performance of new and existing buildings and for standards for the environmental product declaration of construction products, in the framework of the integrated performance of buildings. The becoming standards will be applicable and relevant for the assessment of buildings over its life cycle. The CEN/TC 350 (CEN 2005) work programme will provide a reference framework for combining into an integrated whole the relevant environmental and health outputs of the horizontal test standards for the release of regulated dangerous substances from construction products developed according to the mandate M/366. The results from the standards mandated by the M/330 (energy performance directive) (EEC 2006) are integrated into the assessment of the environmental performance of buildings in the framework of integrated performance of buildings.

The harmonisation of the contents and outline of construction product information will probably go on and also extend to service life aspects of products. Thus the European building product information harmonisation will probably cover all essential parts of construction products information significant with regard to service life design and design for sustainability. When drafting and developing product related information management, developing product information catalogues and the role of product information in product models, these scenarios should be taken into account in Europe. The results from harmonisation will probably significantly facilitate the development of practical systems.

5. CONTENTS AND NEEDS OF PRODUCT INFORMATION

5.1 Needs of product specific information

Present building process practise - to some extent - ignores product-specific information. This happens at least of partly because of lack of tools and relevant databases and existing routines. However, the need of product-specific information has increased mainly because of two reasons: service life and life cycle design requires information about building products; the supply of products and product alternatives has increased.

Life-cycle management and consideration of health risk aspects of buildings require that product-specific information is available on life cycle costs, environmental impacts, and use of chemicals, care and maintenance methods and periods of renewals. On the other hand product-model based building facilitates the inclusion of product-specific information in building design and in the formulation of care and maintenance 'manuals'. Established methods and practices to include products specific information into building specific product models do not exist, but these have to be developed and agreed upon.

The abundance of building products and alternative choices increase and have increased significantly during the last decades. In Europe the increase is based on the opening of the EU internal market and the increased supply of product alternatives.

Table 1 characterises the needs of product information in different task of design, building and maintenance.

Table 1: Needs of product information in different tasks of building and maintenance process.

	TASK	NEEDED INFORMATION
1	service life design	preconditions (concerning assembling, details and structures, use and environment) that are necessary for the estimated service life. Alternatively: the corresponding information in a format of a computational programme with help of which the effect of these parameters can be calculated
2	design for required building performance	technical performance
3	life cycle assessment of building parts and buildings	environmental profile and estimated service life and renewal periods of components and coatings
4	estimation of life cycle costs	cost information including costs from workmanship, estimated service life and renewal periods of possibly included components and coatings
5	design for healthy indoor conditions	indoor air emissions, preferably in terms of classification
6	design for low environmental risks	information about product composition, use of chemicals and emissions to land and water during use
7	design of care and maintenance and scheduling operations	estimated service life, renewal periods of components and coatings, requirements with regard to inspections, care and maintenance
8	care and maintenance	system specifically grouped and scheduled data of all care and maintenance measures
9	reuse and recycling products or disposal of products after service life	manufacturers guidelines for reuse, recycling and disposal (compare 6)

5.2 What is product specific information

Different levels of product information can be distinguished. These levels are characterised according to the source of information as follows:

- Product-group-specific product information:
  Information formulated by a group of producers. Information is relevant for all products of the group and thus the nature of it may be generic.
- Product-specific product information:

Information is relevant for specific products defined. Manufacturers are basically responsible for the validity of information.

- Individual product and batch specific information:
  Information is relevant for individual products or batch defined. Manufacturers are basically responsible for the validity of information.
  Information presents detailed product and batch specific information. This information may be needed in renovation, alteration of purpose of use or repair of serious damage. Information is mainly needed for load bearing structures only.

For example, information on environmental performance of hollow core slabs may be typical or average information concerning a group of products, it may average or characteristic for the products of one specific manufacture of it may be valid only for one specific product. Different levels of information are needed in different stages of building process, and it is important to be able to distinguish between the different levels.

Building products can be characterised on the bases of technical and other properties and on the bases of their performance in buildings. Here the following outline is used:

- Material characteristics:
  Material characteristics can be outlined as mechanical, thermal, optic, electric etc. properties (as outlined by CIB Master List and others). Based on research results, we have knowledge about typical behaviour of different materials.
- Technical properties of products:
  Building products can be characterised in terms of technical parameters.
  Different kinds of properties are important for different product groups.
  In order to compare products on the basis of technical parameters, test methods have to be specified. There are national and international standards for test methods.
  Technical properties of products should form a basis for design for technical performance and service life of building parts. Information on technical properties of products should be available in design.
  European product standards address technical specifications for different product groups.
- Other properties of products:
  Life-cycle design and design for health and low-risk environment require information on other properties in addition to technical properties. These include Life cycle Inventory (LCI) information, information on other environmental aspects (recyclability etc.), service life information, information on indoor air emissions, and information about the use of chemicals.
  International and European standards are being developed in order to outline the life-cycle and health related properties of building products. National concepts exist (for example the EKA concept in Finland described in Häkkinen 2004b).
- Technical performance of building parts:
  Performance can be defined as the ability of a building or part of building to fulfil required functions under intended use conditions or behaviour when in use (ISO 6707-1) (2004a). U-value, sound reduction index, impact-sound level index and fire rating are examples of technical performances of building parts.
  In most cases there is no linear or direct relation between technical parameters of products and technical performance of building parts.
  On building level, product-related requirements should be given in terms of required performance and corresponding required technical and other parameters.

The following text summarises the inclusion of product information to product models in the different stages of the process. The discussion is based on the division of the product model into four separate models as described in section 4.2.

Requirement model should include site and building level requirements, requirements for spaces and building parts but does not include product specific requirements.

Design process should follow the requirements according to the requirement model and include the information about the designed spaces and building parts accordingly. At the same time the design states requirements for the selection of products. The purpose of these requirements is to ensure that the required performance of building parts and spaces will be fulfilled. Design makes use of product-group specific information (before a decision about a specific manufacture) and uses this and product specific information as reference information when formulating requirements for product selection. These requirements are given in the design model within objects. Design process may carry out searches concerning the availability and supply of products having certain properties looked at. Design process also uses separate analyses and simulation models for comparing alternative design options and when seeking best solutions for example with regard to indoor conditions, service life, energy and environmental efficiency. The service life estimation models and environmental assessment models often make use of product-group-specific information in their own data bases. The relationship between product-group-specific information and product-specific information may be problematic in design process. Evidently, design cannot only use product specific information, because the final selection of products has not yet been done and the design process cannot give requirements for products in terms of commercial products. Design process may give requirements with reference to existing products demanding that the corresponding properties should be fulfilled. However, the harmonised product standards will significantly clarify this situation in Europe. The references are not necessary to be made to products but to the required values of technical performance and environmental impacts can be presented. There is and there will be a lot of product specific information available, because the availability of this information in all those formats that are used and required by designers and contractors is in the interest of manufacturers and suppliers. However, although product-group-specific information and generic information would be useful from the point of view of design process, the availability of this kind of information is uncertain.

Building process should make the selection of products so that the product related requirements are realised. It is a significant advantage for the quality of building and the construction process, if the product requirements are given in terms of required technical properties, environmental impacts etc. In addition, construction process would benefit from possibilities to search products with reference to the properties of products. The construction process would also benefit from the possibilities to intelligently transfer and include product data into the building model. The building model (as built) should include all product-specific information that will be necessary for the use phase of the building. This may also include product specific information that is specific to those individual products delivered to the site.

Maintenance model should be a structured data set that includes information needed for care and maintenance arranged with reference to systems that are maintained. The maintenance process does not maintain products but systems including constructional systems like roofs, windows and outdoor walls and naturally building services systems. Important is the support for the grouping of information for example with regard to different building systems, scheduling of measures and support for searches like for example in terms of environmental and health impacts.

6. EXAMPLES OF BUILDING PRODUCT INFORMATION FORMULATIONS AND DATABASES

6.1 Service life information of building products

At present building product information in Finland is given mainly with help of:

- product files and brochures which are sent by post to customers and partners. Product files may include detailed design guides (for example the maxit file includes detailed design information for masonry products).
- product information given via Building information foundation. Includes free text given in certain outline with regard to main headings. Delivered through internet in html format, also available in paper versions. Information can be searched by manufacturers, product groups.
- manufacturers' own web pages.

All these means of information delivery are practically comparable in the sense that those do not support the comparison of products or search of products having specific properties or transfer of information. The LifePlan research project (Häkkinen et al. 2004a) developed the content and presentation of product specific service life information. The objectives of the project were:

1. to define the contents of product specific service life information;

2. to create a product-specific data base for service life information of building products and components;
3. to develop the structure, format and transfer of service life information in user-friendly format, which is compliant with the future product model based software products.

The research resulted in the description of the contents of service life information and introduces how it is used in the different stages of building process. The final results of the research project also include a database prototype. This database includes service life information for 125 products used in building. The project defined the service life information with using XML description language. The LifePlan database is web browser based. The LifePlan database enables the user to browse and search service life information of different products. Information can be searched on the basis of the manufacturer name, the Finnish building classification system BUILDING 90 (RTS 2006a) or with help of free search as indicated in Fig. 2 (VTT 2006a). Fig. 1 presented in section 4.1 shows the principal solution of the database. The principal solution was originally developed in the LifePlan research project (Siltanen 2004 in Häkkinen et al. 2004c) and later further improved by Ilkka Heinonen in the DESNET (DESNET 2006) and IWLORB (IWLORB 2006) research projects.

FIG. 2: LifePlan database.

The LifePlan concept was originally planned aiming at the creation of a database which would finally include the service life information about hundreds of products available for the use of service life design and for the formulation of maintenance manuals. However, in one-actor-centred process like in an owner-centred building process, the system does not necessarily have to be an existing data base, but an existing facility. The process could operate in such a way that the owner requires all the suppliers of the project to include service life information into the database with help of which the compiler of the maintenance information collects and arranges the building information to form building systems specifically organised and scheduled product information for care and maintenance.

The LifePlan project outlines the product information as follows (Häkkinen 2004a) (Table 2, Fig. 3):

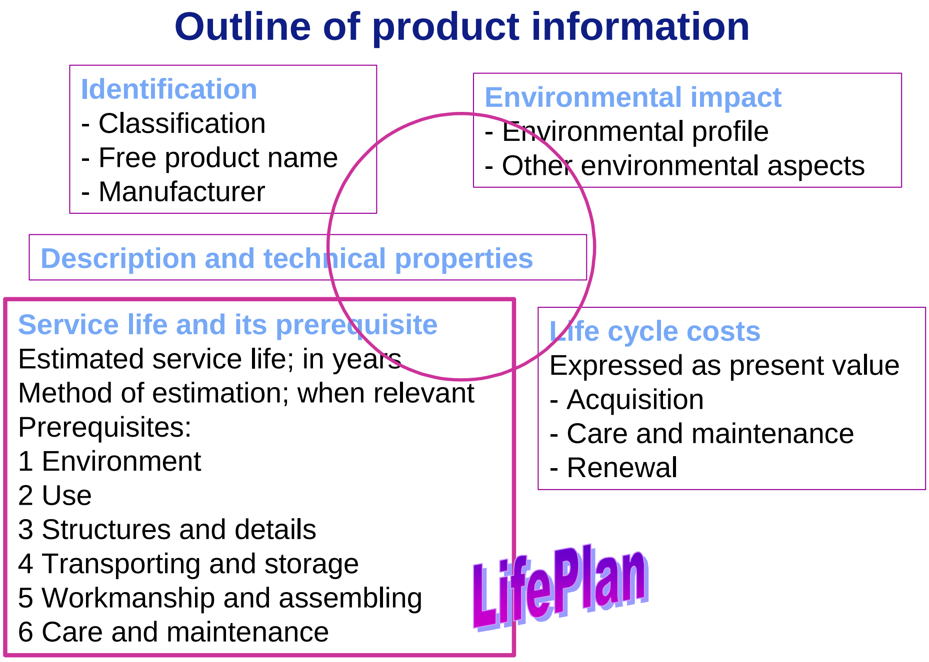

FIG. 3: LifePlan outline for product information.

Table 2: Product information according to LifePlan.

1	Identification	
	1.1	Classification
	1.2	Free product name
	1.3	Manufacturer
2	Description and technical properties	
	2.1	Description (shape, dimensions, tolerances, density, colours etc)
	2.2	Technical performance
3	Service life and its prerequisite	
	Estimated service life (in years)	
	Method of estimation (when relevant)	
	Prerequisites:	
	3.1	Environment
	3.2	Use
	3.3	Structures and details
	3.4	Transporting and storage
	3.5	Workmanship and assembling
	3.6	Care and maintenance
4	Environmental impacts	
	4.1	Environmental profile
	4.2	Other environmental aspects
5	Life cycle costs (expressed as present value)	
	5.1	Acquisition
	5.2	Care and maintenance
	5.3	Renewals

LifePlan describes the use of service life information in different stages of building process as follows:

- formulation of service life requirements for building parts on the basis of building level service life requirements (at this stage product information may be needed as reference information);
- service life design of building parts;
- life cycle assessment (environmental impacts assessment) (information about care and maintenance measures and the predicted number of renewals during the studied time span is needed);
- life cycle cost assessment (information about care and maintenance measures and the predicted number of renewals during the studied time span is needed);
- formulation of quality requirements for products with reference to the designed service life values;
- formulation of product-related information to maintenance manual.

LifePlan database supports service life design by presenting product-specifically:

- the estimated service life of the product;
- the computational method for service life estimation (when it exists);
- the dependency of service life on environmental conditions and surface treatment (when relevant);
- guidelines about the suitable environmental conditions, use, structures and structural details as well as care and maintenance when these are necessary preconditions in order to achieve the estimated service life.

The LifePlan project defines that the estimated service life is a numerical value of predicted service life. The basic idea is that the manufacturer of the product presents the estimated service life together with the defined preconditions. The estimated service life is defined with regard to the wholeness of the product that the manufacturer brings to the market no matter of the hierarchic level. During the estimated service life, certain parts of the product may be necessary to renew. This information has to be given in the context of maintenance information. Service life has to be estimated in years and it cannot be a range. It is assumed that the estimated value will be exceeded on the 95% probability.

Computational service life prediction methods support service life design. According to the LifePlan concept, the manufacturer may present coefficients with regard to environmental conditions and surface treatment when there is no existing method. At present the referred computational methods are mainly the so called ENNUS methods. These are service life prediction methods for exterior walls and roofs developed at VTT (VTT 2006b). The ENNUS methods outline the service life behaviour on the basis of the factor method presented in ISO 15686 (2000).

The design life of building products should be defined on the basis of the design service life of the building, the required adoptability of the building and the objectives concerning serviceability and maintainability (as well as the tolerance of the disturbance caused by those). Service life design should results in:

- estimated numerical service life values (greater than the stated design values)
- guidelines for care and maintenance; it should be noted that because care and maintenance is done for systems instead of individual products, care and maintenance information should given and grouped correspondingly;
- requirements for construction and procurement; these requirements concern those technical and other properties of products that are necessary preconditions with regard to the designed service life.

6.2 Environmental information of building products

The so-called EKA (Häkkinen et al. 2004b), (Häkkinen 2004b) research project developed a methodology for the environmental assessment of building products and formulated the structure of environmental declarations.

The EKA method is a voluntary national method for the assessment and reporting of environmental aspects of building products and buildings. The method includes the following issues:

- principles for data collection and data handling (LCI);
- generic environmental profiles for energy and transportation;

- declaration format;
- auditing, approval and publication principles of declarations and
- principles that should be followed when using the environmental profiles of building products within building design.

The Finnish Building Information Foundation has adopted the methodology and publishes the declarations in pdf format in its web pages (RTS 2006b). However, the EKA project also defined the IFC compatible property set for environmental performance of building products (Juha Hyvärinen, VTT). There was an option to include the environmental information into the LifePlan database, but this has not yet been realised. The EKA method outlines the environmental declaration as follows (Table 3).

Table 3: Detailed environmental information according to EKA.

Product definition	
1	Identification (Classification (number), Manufacturer, Product name)
2	Description (Short free-form description)
3	Conversation factors (volume weight, square weight, moisture content)
4	Technical performance
Environmental profile	
5	Use of resources
5.1	Energy (according to the given outline)
5.2	Natural raw materials (Renewable / Non-renewable / Hidden flows)
6	Emissions
6.1	Emissions to air (CO_2, SO2, NO_x, CH_4, N_2O, NMVOC, PM_{10}, Heavy metals)
6.2	Emissions to water (COD, BOD, P_{tot}, N_{tot})
6.3	Wastes (Dumping wastes, problem wastes)
Other environmental aspects	
7	Transportation of product (typical length and means of transportation)
8	Indoor air emissions (according to the classification followed in Finland)
9	Health risks (reference to a possible operational safety bulletin)
10	Service life (reference to possible LifePlan /2/ information)
11	Care and maintenance (Assessed main material and energy flows because of care and maintenance)
12	Final disposal (Recycling / Energy use / Type of waste)

7. DISCUSSION

Research and development and practical examples show that there are technical alternatives to build databases which include building product information in a format that is computer interpretable. For example the LifePlan project built a database for service life information and defined this structured information using XML description language.

We have technical alternatives to develop databases, but on the other hand it seems that we do not have common understanding about the use of these databases. On the basis of literature it seems that the first intended purpose has been to support search of products having certain technical or other performance. However, on the basis of the research projects carried out at VTT in this area, this purpose does not seem to be the primary need. During a design process designers are not necessarily capable to make focused searches because they often do not know the specific performance factors and performance limits that should be searched. However, the design team needs product information in order to use this as reference information when formulating product specific requirements.

There is a wide and intensive standardisation work going on in Europe that finally aims at harmonising technical performance, environmental performance, health, and service life information of building products. This process will both support designers in getting information about product group specific relevant properties to search and acceptable limits for these properties.

Design process also needs background information for different kinds of analysing and simulation programmes. At present this is typically organised so that these programmes include the needed background database. However, for example LCIs could also be organised so that the programme would use a database kept up by another actor providing that the needed information was given in a format that is compatible with the assessment programme. The obvious advantage would be that there would be one actor who would take care of the up-dating of information for all users of this information.

For example the Finnish Building Information Foundation has started to publish structured information about the environmental profiles and other environmental aspects of building products (RTS 2006b). At present this information is given in pdf formats and thus it is not interpretable for programmes. However, for example with help of using the LifePlan concept and giving the information with using XML description language the intelligent use of information could be organised.

Additionally, it should be considered whether certain analysing capabilities should be included in the product model itself. This would help the design process to carry out for example environmental analyses continuously during the design process when formulating alternative design options. However, in this case too, the product database including the environmental profiles of products should preferably be a separate database (a database kept up by another actor) for the reasons explained above.

In a traditional structural design task the performance of products is dealt with in terms of a group of parameters for which the designers - as the result of the design task – state required values. Design methods have also been developed to design for durability and service life. These methods deal with products with help of durability parameters. Correspondingly, the result of a design task is the information about the required values. Accordingly, design for acoustical, thermal etc. performance can be seen as a task where the designer operates with parameters and finally states the required values for products.

However, there are also building parts and products which are not necessarily objects of design in the sense described above. However, for those products too the designer should be able to state requirements in terms of required performance. Product information databases should be able to support designers within these tasks - if not primarily in searching products - but in searching information about product group specific performance in order to state requirements. The European harmonisation work on technical and environmental performance will probably help to organise this kind of databases.

In summary, on the basis of the LifePlan project experience, the designers need product information for two main purposes: 1) to analyse and simulate design options; 2) to define product specific requirements for building phase and the procurement of products. Primarily the needed information is not product specific information, but generic or product group specific information. Product information is needed as reference information when formulating requirements for products.

In an ideal case the design process starts from the identification of the stated requirements. Design process aims at producing a design option which fulfils the stated space, performance and life cycle requirements. This is done with help of design tools, simulation and analyses models. The product level information is given in terms of required properties, the realisation of which is a prerequisite for the design option to fulfil the building part and building level required performance. The product level requirements should be defined as attributes for design objects. With regard to information contents these requirements should follow the information structures agreed upon within product standardisation. The selected products in the design model should be identified with help of product codes.

The production stage needs product specific information databases in order to seek products that fulfil the stated requirements. Here again the structure of the delivered information should consider the on-going standardisation work. The real product specific information of the selected products supplied should be linked to the model with help of product codes.

Ideally the product specific information of all products that will be objects of care and maintenance should be collected to a database with help of which the maintenance operations could be possible to be planned and scheduled considering the product specific requirements with regard to care and maintenance, and taking into account that maintenance operations are carried out for building systems instead of individual products.

The problematics concerning the transfer of product specific information from manufacturers to the information systems of other actors are especially important and relevant with regard to these stages (as built, as maintained).

Product specific information is not necessary to be included in the design model. The design model should identify the products with help of codes and give requirements or references for the selection of specific products. Product specific information should be included in the model that can be called 'as built'. The product specific information to be transferred to the building and maintenance models should be structured information defined with help of product codes, the transfer of product specific information from product libraries should be very simple and automatic loading to the building database should be supported. Simple XML applications should be considered. In every case common agreement upon languages to be used should be achieved.

As introduced above the LifePlan research project defined service life information using XML description language. In one-actor-centred process like in an owner-centred building process, the system does not necessarily have to be a database, but for example an XML based schema compatible with product model according to which suppliers are asked to project specifically provide all service life information.

Fig. 4 summarizes the place and role of product information in different stages of building process.

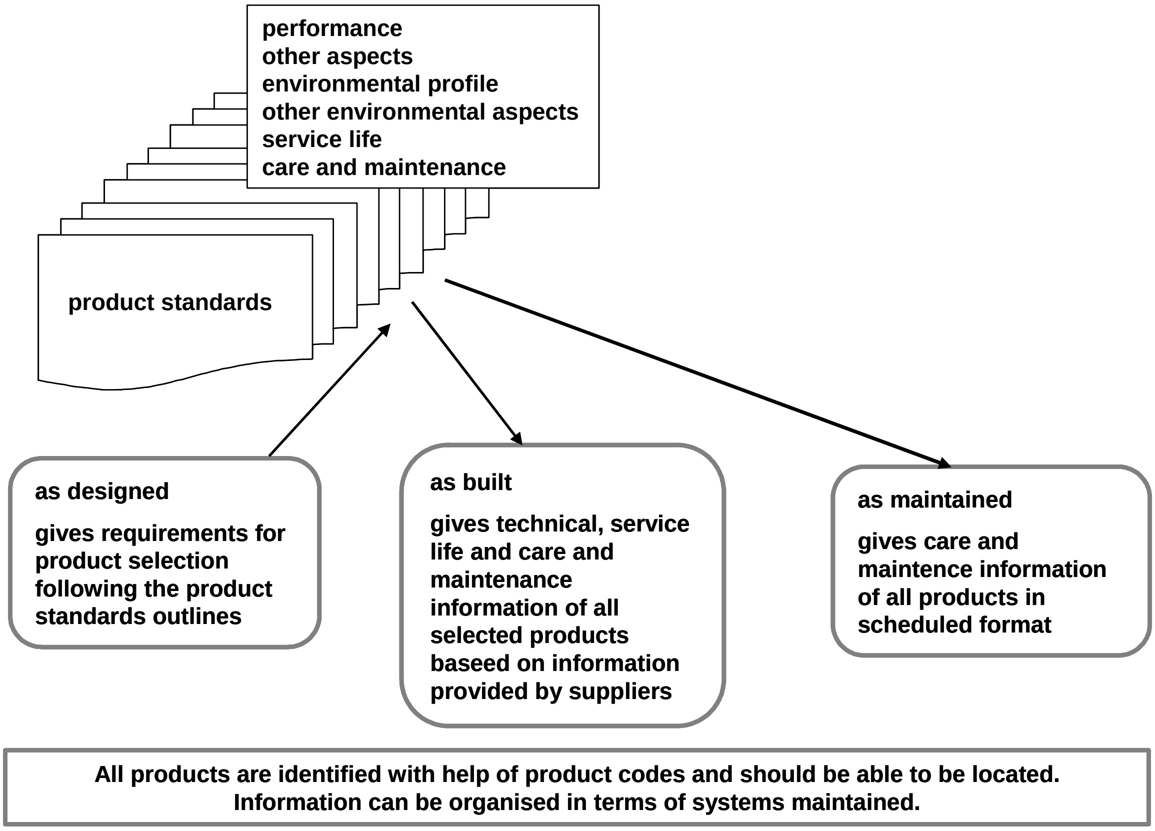

FIG. 4: Place and use of product information in different stages of building process (rounded rectangles) and contents of product information (rectangle) given with help of standardised product information (multi-documents). Design process gives requirements about the selection of products, while building and maintenance processes use product information in selection and maintenance.

8. SUMMARY

This paper summarises the recent results from studies carried out at VTT concerning the contents of construction product information and its use in different stages of building projects and building maintenance. The study has two specific points of view: increasing needs of product information based on service life and life cycle management of buildings; potentials of new information technological solutions for information transfer and use to support the product related information needs.

The paper describes, gives examples and defines the contents of building product information needed from the view point of life cycle design and maintenance of buildings. The study considers the latest developments in the standardisation work of building product information standardisation (especially from the European point of view). In addition, the paper drafts principle solutions for the use of product information in product model based building.

One of the desired benefits of internet based building product information delivery is the possibility to search for products with reference to their characteristics. Product characteristics are always connected with the method of measurement, suitable methods are different for different products and product groups and relevant characteristics are different for different kinds of products. Rational search will only be possible if products can be specified in terms their characteristics and performance. However, product specific information is not only needed for searching products that have certain characteristics. Requirements verification, service life design, life-cycle assessments, as-built information and care and maintenance information need product-based data. Many research projects have already introduced information technological solutions alternatives for data search and selection, delivery of information through product libraries, data exchange, and data storage in different models. However, the realisation of these potentials requires a common understanding about the contents and use needs of information, for the management of which these systems are planned.

The LifePlan concept was planned aiming at the creation of an extend database of product specific service life information. However, the extension of the database after the project has shown to be difficult. It is notable that in one-actor-centred process like in an owner-centred building process, the system does not necessarily be an existing data base. The process could also operate in such a way that the owner requires the suppliers of the project to include service life information into the database with help of which the compiler of the maintenance information collects and arranges the building information to form building-systems-specifically organised and scheduled product information on care and maintenance.

Current design software products support the formulation of information that is created in the design process - first of all geometrical information. It has already been shown in the Finnish ProIT project that building an interoperable system for the management of bill of quantities and cost accounting can be realised effectively. Building level environmental assessment with help of environmental profiles of products should be feasible correspondingly.

Product manufacturers and suppliers already provide information on their products covering technical, environmental and health aspects of products. The existing data are not in a coherent and automatically usable format. There is a need to start to produce common understanding not only for the content and contentual structure of this information but also for the format of the product information.

9. ACKNOWLEDGEMENTS

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