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Automatisation of Building Life-cycle Assessment

Parsing Bills of Quantities to Enable Early Building Life-Cycle Assessment

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This Bachelor's thesis aimed at identifying potential ways to automatise the process of building life-cycle assessment, which is based on bills of quantities and industry foundation classes (IFC). An improved assessment is meant to make a life-cycle analysis (LCA) quicker and easier.

Construction project developments in Germany, Great Britain and France were reviewed to find out when and in which form electronic documentation is exchanged between the project stakeholders. Documentation susceptible of containing information relevant for an LCA was taken into closer consideration. In Germany, XML data was found to be widely used to write bills of quantities and calls for bids. In Great-Britain, standardised spreadsheets in the COBie format were found, as well as Uniclass building element classification. In France, no standard documentation format was found. However, recent government incentives suggest a future development similar to Great-Britain, based on IFC and spreadsheets.

The final year project found optimisation potential of LCA through computer-based analysis of electronic documentation. The result can be used to start working on parsing engines for the formats XML, COBie and Uniclass.

Keywords	LCA, Sustainability, United Kingdom, Germany, France

Contents

1 Introduction

Life-cycle analysis is an important part of voluntary building environmental certifications. In the near future it might become compulsory in some European countries for every building endeavour to show the life-cycle assessment (LCA) of the project. In this respect, this Bachelor's thesis focuses on automatisation possibilities of LCA for buildings. The paper examines the possibilities to automatically identify the components of a building in the bill of quantities and to match them with the entries of an LCA-database in order to compute the environmental impact of the building as early and as quickly as possible in the construction process. The focus is laid on finding a practical and quick way of doing this.

The first part of the thesis describes the process of life-cycle analysis. The second gives an overview over construction project development in Germany, in the United Kingdom and in France and lists what documents, mainly bills of quantities, are produced at which stage of the project. The last part focuses on systems that have been adopted to facilitate the transmission of data between the stakeholders in a building project in those countries. For each one, the paper suggests possible ways of gathering information at an early project stage.

Because of the rapid pace of development of the industry and its techniques, most of the literature used here is unprinted and only accessible in a digital format. Currently, the automatisation of life-cycle assessment is the matter of a handful of companies worldwide, and literature, experience and know-how regarding it is jealously kept from others. Therefore, the bulk of the information contained in this document was received directly from companies in the field.

2 Building Life-cycle Assessment

2.1 Definition and principle

A life-cycle assessment (LCA) is the "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life-cycle", as is mentioned in the corresponding ISO standard [1]. In the particular case of a building, the European Standard EN 15978 “specifies the calculation method […] to assess the environmental performance of a building, and gives the means for the reporting and communication of the outcome of the assessment. The standard is applicable to new and existing buildings and refurbishment projects.” [2.]

Currently, LCA is not required by law in any European country but things are changing fast in that direction. Already the Netherlands demand developers and building owners to provide a study of the carbon footprint of any new construction project [3], and France has a similar law project in the making [4]. Mostly, LCA is included as part of the environmental certification of a building. The environmental certification is usually a voluntary process motivated by the good publicity of sustainable buildings and the resulting high return rate to the investor. There are many different environmental certification schemes and the scope of the LCA they demand varies from one to the other. [4, 5.]

2.2 Information collection for an LCA

Building life-cycle assessment often relies on environmental product declarations (EPDs). EPDs are created by the manufacturers themselves for each of their products (product-specific EPD) or by third-party organisations to assess the average environmental impact of a product type (generic EPD). Environmental product declarations can be formatted according to different standards. In Europe and in European certification schemes, the EPD produced according to the European standard EN 15804 or Type III environmental declarations according to ISO 14025 are considered as the most reliable ones. [5.]

EN 15804 defines the core rules for assessing the environmental impact of construction products in general. When necessary, specific product rules are defined for specific product categories. An EPD according to EN 15804

> provides quantified environmental information for a construction product or service on a harmonized and scientific basis. It also provides information on health related emissions to indoor air, soil and water during the use stage of the building. The purpose of an EPD in the construction sector is to provide the basis for assessing buildings and other construction works, and identifying those, which cause less stress to the environment. [6.]

Apart from all the parameters affecting the environmental impact of the product, the EPD also features important information identifying the product, such as what the product is made for and the functional unit of for which the data was analysed [6]. This information is very important. According to Panu Pasanen, CEO of Bionova, a company specialised in building LCA and its automatisation, product-specific EPD are in the minority. Life-cycle analysts often fall back on generic EPDs or use an EPD provided by another manufacturer. It is hence important to know whether the EPD and the actual product are comparable for the LCA to be valid. [Panu Pasanen, CEO, 14 April 2016, personal communication.]

EPDs are public documents, stored in various online databases. When assessing the environmental impact of a building, a life-cycle analyst practically sums the impact of each of the components of the building. Therefore, the components have to be identified, their quantity measured and the impacts scaled according to the amount of product in the building. This is currently done automatically using computer programmes as long as the components can be matched with a corresponding EPD. [7.]

The identification and the quantification of the building components themselves is the main purpose of this paper. To this date, this is commonly done using the industry foundation classes (IFC), a range of digital data formats to exchange information on buildings and construction processes developed and maintained by the international interest group buildingSMART. This requires drawing the building with appropriated programmes to create a building information model (BIM). Some commonly used programmes are AutoDesk Revit, Graphisoft ArchiCAD and Nemetschek AllPlan. The IFC model specification is described in ISO standard 16739:2013. For each building component, a class (hence Industry Foundation Classes) provides a particular type of information such as component material or its delivery date on the construction site. Using the relevant industry foundation classes, it is possible to collect all the necessary information for a life-cycle assessment. A few classes are listed in Table 1.

Table 1. Overview of some building component information that can be retrieved using industry foundation classes (IFC).

Information	Corresponding IFC
Name of component	IfcObjectDefinition
Material of the component	IfcMaterial
Composite or simple component	IfcMaterialLayerSet, IfcMaterialConstituentSet

Information retrieval from IFC requires a certain amount of data preparation. This is done using a special engine [7]. The script cleans the IFC file from irrelevant data and structures it on the base of custom filtering parameters to improve material discrimination. Once this is done, it is easier for a human to recognise a given component and assign an EPD to it if it cannot be matched automatically. The complete process of a building life-cycle assessment is illustrated in the diagram below.

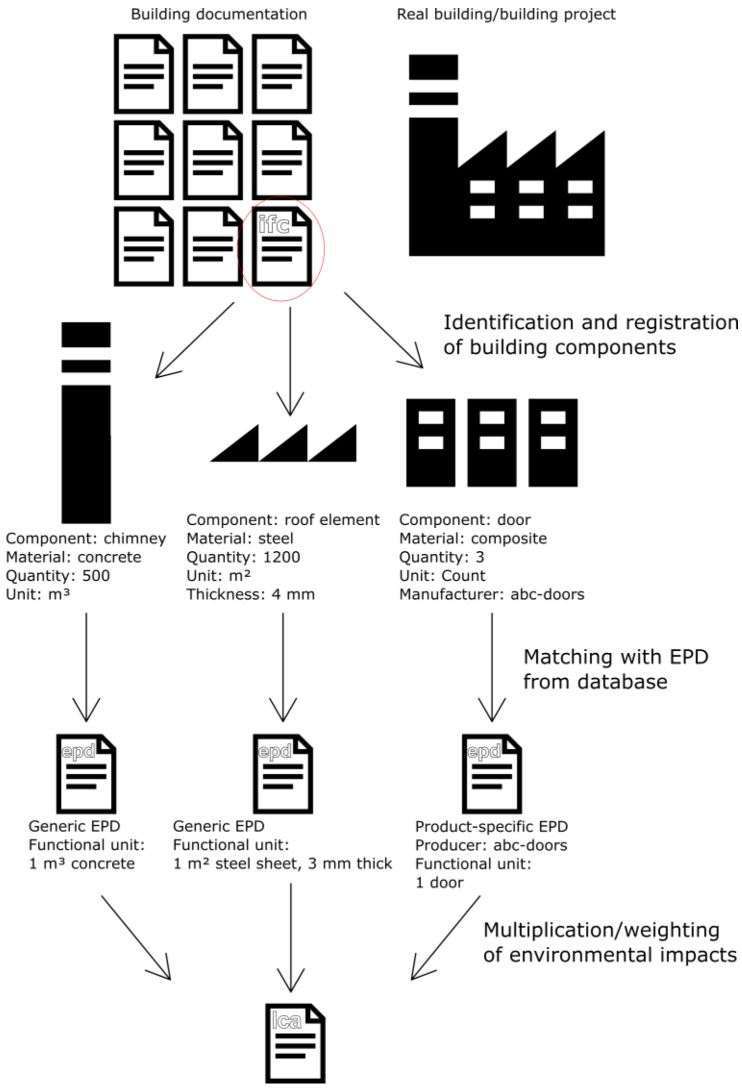

Figure 1. Schematic representation of the information path from the real building (existing/in project) to the results of the life-cycle assessment.

The purpose of this paper is to identify which documents or data other than the IFC model can be used to produce a detailed list of the building components. For this, it is necessary to glance at the documents produced in the course of the building endeavour.

3 Development of construction projects

In the European Union, the tendering process for public construction projects is guided by the directive 2014/24/CE. This chapter will go through the phases of a common construction project in the United Kingdom, Germany and France. For each step, the documents that need to be provided will be mentioned.

3.1 Construction project phases in the United Kingdom

The Royal Institute of British Architects (RIBA) publishes a standard Plan of Work as a template for all construction projects. The latest edition dates from 2013. The RIBA describes the template as “the definitive UK model for the building design and construction process” [8]. It consists of eight steps, described below.

The **Strategic Definition** is the first stage of a construction project, the architect needs to identify the client's strategy behind the project and his financial rationale. On these findings, the architect establishes a project programme and leads pre-application discussions with the authorities. [8.]

During **Preparation and Brief,** the architect develops, in cooperation with the client, the project’s objectives further, including the quality level, the sustainability objectives and the budget framework. He also orders feasibility studies and reviews the site information. Pre-application discussions continue. At the project team level, members are hired and responsibilities are distributed to create the contractual tree. [8.]

The **Concept Design** is the first design. It includes outline proposals for structural design, building services systems and outline specifications. On the basis of the project programme, the architect provides preliminary cost information. In the conceptual estimates, actual quantities do not play a large role since historical price ratios per unit of surface area (based e.g. on the quality of the structure or the systems) are used [8]. The final project brief is issued after final modifications. The project programme is updated. [8.]

At the **Developed Design** stage, the architect develops all the aforementioned aspects of the concept design into a developed design. The project programme sets out the specific stage dates and detailed programme durations. Using the developed design, it is possible to apply at the planning authorities for building permits. It is also the phase when the cost estimation, based on the quantity of each the building components, is updated. [8.]

The **Technical Design** follows the Developed Design and should feature all architectural, structural and building services information, specialist subcontractor design and specifications, as stated in the design programme. [8.]

During the **Construction** phase of the project, the architect oversees offsite manufacturing and onsite construction as stated in the construction programme. Additionally, he answers to design queries from the site as they arise. The architect manages the building contracts, including regular site inspections and review of progress. At **Handover and Close Out**, the architect supervises the handover of the building and the conclusion of the building contract. When the operation of the building starts, the architect provides **In Use** services as agreed upon in a separate schedule of services. [8.]

3.2 Construction project phases in Germany

In Germany, the phases of a construction project are formally given by the remuneration regulation for architects and engineers (*Honorarordnung für Architekten und Ingenieure*) [9]. It is divided in nine achievement phases (*Leistungsphasen*, LP) as described below.

For the **Base inquiry**, the architect prepares an overview of the requirements for the building to be built or renovated. The overview is the result of discussions with the client regarding his idea of the building and his financial capabilities. [9.]

In the **Pre-design** phase, the architect proposes pre-plan drafts of the building. In the floor prints, sections and elevations, it is already possible to recognise the expectations of the client. The function of the rooms, their size and the shape of the building is also clear. This is the moment of the first formal cost estimation, known as *Kostenschätzung*. Preliminary contacts are made with the authorities to inquire upon the authorisation of the project. [9.]

The following design stage, known as **Draft design**, is a complete draft of the building. The form and function as well as technical, mechanical and economical aspects are taken into account on the grounds of the feedback from the other specialists taking part in the planning process. The result is a plan at a scale 1:100 or 1:50. The discussions with authorities that were begun at the pre-design phase continue. The corresponding cost calculation is called *Kostenberechnung* and it is subdivided into normative building parts (walls, roofs, slabs, etc) as found in the German standard DIN 276. [9, 10.]

In Germany a special plan, called **Authorisation design** and based on the draft design, is required to search the authorisations and permits required for construction. The architect prepares the applications and leads the discussions with the authorities. He consequently updates the plans.

The detailed implementation of the building endeavour is planned in **the Implementation design** phase with all stakeholders. The architect updates the drawings in functional, technical, mechanical, economical and energetic aspects and produces an implementation-ready design, which integrates the complete work of the building services engineers (heating, ventilation, air conditioning, plumbing, electricity, automation). He provides the drawings for all necessary details in the scale 1:50 to 1:1 and updates them during the construction phase. The cost of the project is estimated according to DIN 276 based on either unitary or fixed prices.

During the **Preparation of the tendering**, the architect records every building component and creates the bill of quantities. The architect prepares a description for each task according to its building service type and coordinates them with the other stakeholders involved in the planning. He prepares the allocation schedule and inquires the costs on the basis of the bill of quantities. The architect also **participates in the tendering** and advises the client on the basis of the offers he receives. He leads the tendering negotiations and proposes tenders to the client. He compares the results of the tendering phase with previous cost estimations.

The **Supervision of the construction phase** involves seeking final authorisations and managing contracts with the construction companies. The architect coordinates their work, creates the schedule, documents the construction process with a diary, controls the bills and checks the adequacy of the costs with previous estimations. As-built drawings are produced and the definitive cost of the project is stated according to DIN 276. The project is finally handed over and the deadlines for claiming shortcomings in the construction are set.

After construction comes the **Support phase**, where the architects assesses the building's shortcomings possibly claimed by the client during the guarantee period and supervises the reparation.

3.3 Construction project phases in France

In France, the law 85-704 frames the relationship between a client and his contractors in public construction projects [11]. For the **Sketch studies** (*Études d'esquisse*, ESQ), several general solutions are proposed and the feasibility of the operation is assessed. The **Pre-project studies** (*Avant-projet sommaire/détaillé*, APS, APD) precise the general composition of the project with plans and volumes, to define a completion schedule and a provisory cost estimate. The client approves and locks the design. The **Project design** (*Études de projet*, PRO) focuses on the exact description of all tasks to be done: blueprints, section plans, elevation plans, detailed cost estimation (*Détail Quantitatif Estimatif, DQE*), which will be used for the call to tenders. After this stage, the client must know how much the construction and the operation of the building will cost. [11.]

The architects help the client prepare the documents necessary for the **call for tenders** (*Assistance pour la passation des contrats de travaux*, ACT). The complete file is called a Company Consultation Folder (*Dossier de Consultation des Entreprises*, DCE). Once the call for bids is over, the client assesses the offers of the companies and eventually signs a contract with the company of his choice, that will then implement the designs. [11.]

During the **Direction of implementation of work contracts** (*Direction d'exécution des contrats de travaux*, DET), the architect oversees the construction process and makes sure that the construction company fulfils its agreement and meets the quality standards. He is responsible for the administration of the site. This means that he organises site

meetings and writes minutes, gives the green light for new work phases, takes side in case of divergences regarding work quality. From an economic point of view, the architect must approve all bills before sending them to the client, and upon handover, prepare a General Final Breakdown of the total costs of the project (*Décompte Général Définitif*, DGD). Additionally, architects are sometimes entrusted with the coordination of the construction site (OPC). While DET deals with the quality of the work, OPC focuses on managing the simultaneous operations on the site: define storage, working and driving areas, create a practical schedule. [11.]
At the handover of the building, the architect assists the client, he writes up differences of opinions between client and constructor. He has a counselling function, the client eventually decides whether to accept the building as it is. Once this is done, the building becomes the property of the client. This assistance is called AOR. (*Assistance apportée au maître d'ouvrage lors des opérations de reception*). The architect is not bound to any service during the operative phase of the building. [11.]

3.4 Levels of development of a building information model

As building information modelling becomes more common in the construction business, it is necessary to assess how precise and trustworthy the information of a model or of one of its components can be considered throughout its development. For this purpose, the concept of level of development (LOD) received a lot of publicity. The BIMForum, an interest group encouraging the use of BIM in the United States, has now formally specified the information threshold for each level of development of a series of building components [12]. Without going into any details, LOD can be divided into five main levels: LOD 100, LOD 200, LOD 300, LOD 400 and LOD 500. A model element with a high LOD provides reliable information. The information that can be retrieved from an object with a low LOD should not be considered reliable for planning. The LOD is supposed to rise throughout the planning phases. Those levels can be subdivided (e.g. to fit customary practices in the company or special project milestones) using the two remaining digits.

A building model element at **LOD 100** does not exist as such. It is a symbol with some values attached (e.g. gross cost or weight per unit), but no geometric representations regarding its shape, size or location in the model. The specification states that "any information derived from LOD 100 elements must be considered approximate". [12.] At **LOD 200**, the element receives a geometric representation as a generic object or system. The physical properties, such as quantities, size, shape, location, and orientation, are still approximate. The element can be considered as a “generic placeholder”, and only approximate informational content. **LOD 300** describes a specific element with its own geometric representation, including the quantity, size, shape, location, and orientation. These values should be reliable enough to be measured directly from the model “without referring to non-modelled information such as notes or dimension call-outs” [12]. Classifying an element as **LOD 400** means that the element has a graphic representation with specific physical properties, and additionally “with detailing, fabrication, assembly, and installation information”. It is considered sufficient in detail and accuracy for production and installation, as well as for measurements without referring to other documents. At **LOD 500**, the building model element is genuinely a virtual representation of the element that can be found on the actual building. It is verified in all terms so as to provide sufficient amount of data for the management of the building throughout its life-cycle. [12.]

It is necessary to keep in mind that LODs are object-specific and that they do not apply to the whole model at once. This means that at every stage of the development, different objects will display a different level of development: as foundation works start, their design will be sufficient for fabrication and installation of the reinforcement bars, while the LOD of the windows may still be generic placeholders in the model with no mechanical requirements or manufacturer linked to them [12]. This has significant implications regarding any cost estimation or quantity take-off: if the quality or the composition of the components cannot be assessed precisely, the cost estimation will not be precise either. [12.]

Figure 2 attempts to compare the development phases of construction projects in Germany, Great Britain and France. It also gives information on the typical level of development of the building model elements throughout the process. On the top, different types of cost estimates are displayed according to the point of the process when they are produced. The tolerance for design changes during the course of the project is given by the blue and red curves. The increasing precision of the cost estimations is displayed in shades of grey.

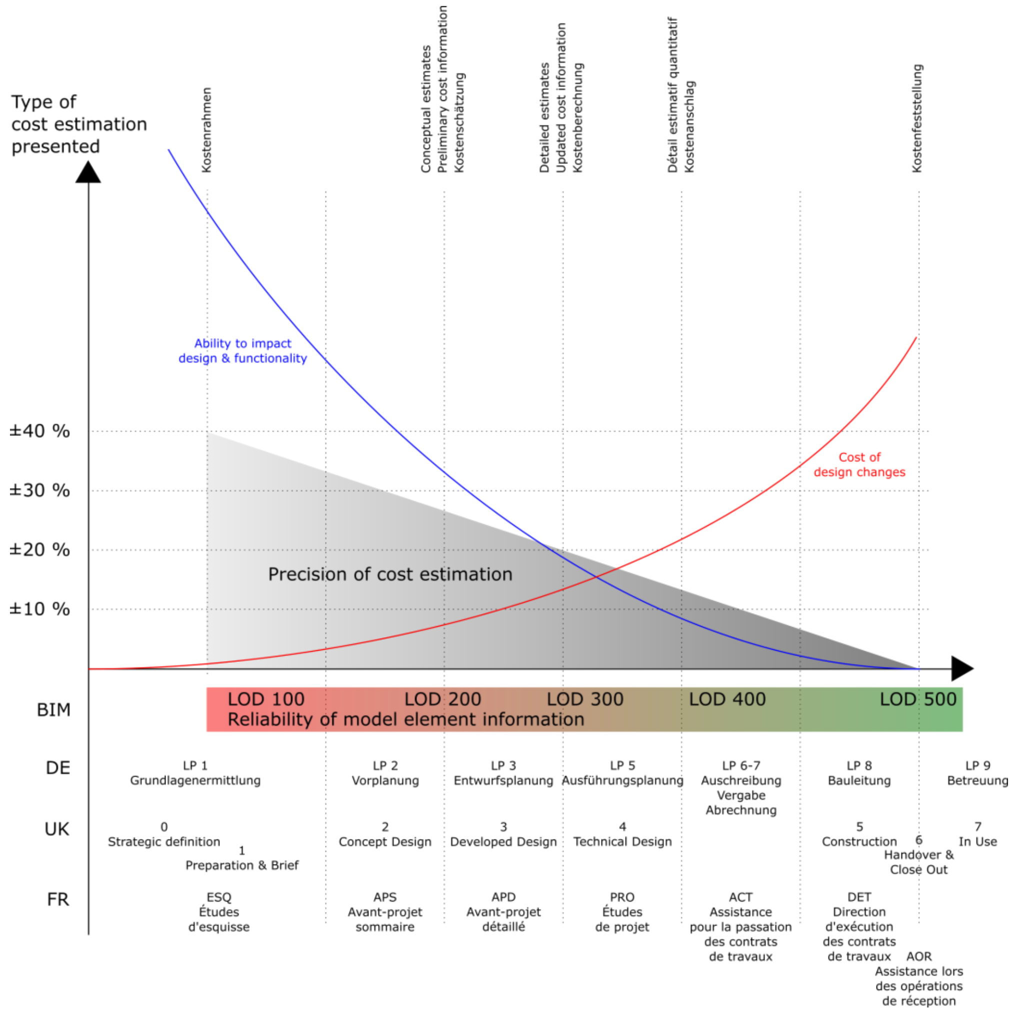

Figure 2. Comparison of construction project development in Germany, the United Kingdom and France, along with corresponding BIM-related levels of development. [13.]

Figure 2 illustrates why, from an environmental point of view, it is critical to get hand on information regarding the building components as early as possible. As was mentioned in Chapter 1, IFC files can be used to produce an LCA. Sufficient level of detail is available at LOD 300 but most of the time the life-cycle analysis is done only in the tendering phase, where all materials and components are specified. [12.]

Considering that information at LOD 300 is already quite reliable, it is worthwhile to strive for an LCA at this stage: indeed, even if the manufacturer and properties of a specific product are not clear, enough is known to link the element to a generic EPD [7.]. This is all that is needed for a preliminary LCA.

However, it might still be possible to use also other channels than IFC to gather information. Below, information exchange patterns among construction project stakeholders in Germany, the United Kingdom and France are investigated. For each country, hints at possible ways of reading the data are given.

4 Information exchange

4.1 Information exchange patterns in Germany

Calling for bids in Germany, Austria and Switzerland is standardised along a similar data format, XML (see below). For the sake of simplicity, only the German system is exemplified in the following.

The description of tasks to be performed on a construction site was standardised by the German authorities in order to avoid misunderstandings in the calls for bids. The use of the Standardised work task descriptions – Construction (*Standardisierte Leistungsbeschreibungen – Bau*, STLB-Bau) is compulsory for Federal construction projects and is widely used in private construction endeavours. [13.]

The bill of quantities according to German standards specifies clearly the type and hierarchy of the task to be performed, the material quantities and their specific unit, a short and a long descriptive text, the unitary price and the total price of the job. Programmes specially designed for tendering, allocation and billing of construction tasks (so-called *AVA*-Programmes for *Auschreibung, Vergabe und Abrechnung*) have sprawled to create those precise entries for each task according to the STLB. [13.]

From the point of view of an LCA, the level of detail of the bill of quantities provides vital information about the building components. By processing the bill of quantities, it is possible to identify all components of the building, even those that might not mentioned in the building information model (BIM). This amounts to a more complete registration of the building materials than the current IFC can do. Currently, modelling ignores nearly two-dimensional elements like paintings, waterproofing and surface treatment. Since bills of quantities include such components, the resulting life-cycle assessment would be more complete.

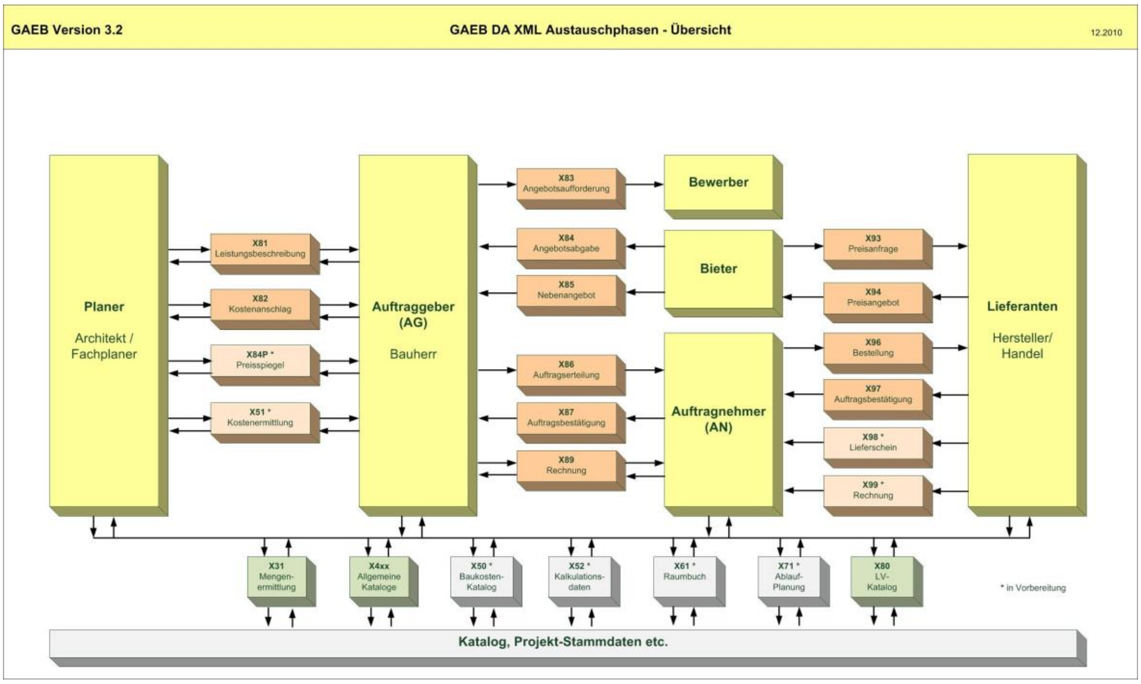

Figure 3. Overview of the information transfer network between the stakeholders of a construction process using the latest version (3.2) of GAEB DA XML. [14.]

The data format used by the Germans for building information exchange is XML. Figure 3 provides an overview of the network between building project stakeholders. According to the relevant W3C recommendation, the Extensible Markup Language, abbreviated XML,

> describes a class of data objects called XML documents […]. XML documents are made up of storage units called entities, which contain either parsed or unparsed data. Parsed data is made up of characters, some of which form character data, and some of which form markup. Markup encodes a description of the document's storage layout and logical structure. XML provides a mechanism to impose constraints on the storage layout and logical structure. [15]

In the quote above, parsed data should be understood as “text, a sequence of characters, which may represent markup or character data” [15]. An extract of an XML data and the relevant printed version are shown Figure 4 below. The name of the product is framed in orange, the quantity and the unit in blue. Relevant additional information (here the thickness of the layer) is emphasised in red. It can be automatically retrieved due to the logic structure of the document

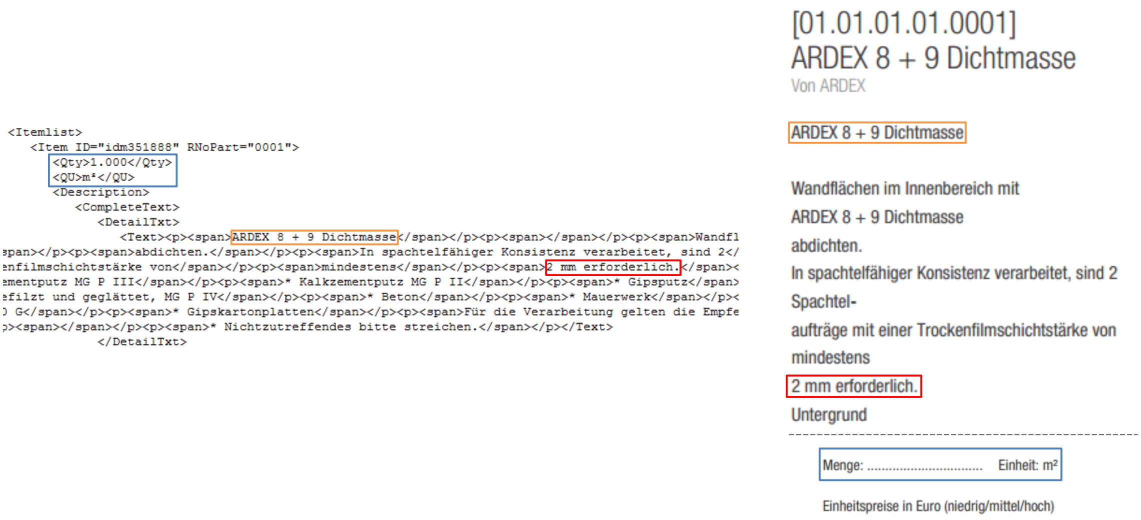

Figure 4. Extract of a dummy GAEB DA XML data and the corresponding rendered bill of quantity.

The systematic description is probably due to the myriad of small sized construction companies in German-speaking countries. Information exchange between companies is more likely to fail than information exchange within companies. For this reason, the creation of a national authority responsible for the creation of a national standard seemed necessary. In Germany, it is the GAEB (*Gemeinsamer Ausschuss Elektronik im Bauwesen*, Joint Committee Electronic in Construction Industry) that issues and updates its GAEB DA XML (*Datenaustauch*, Data exchange) format.

As Konrad Stuhlmacher, a German specialist of building data exchange, mentioned in an e-mail conversation [Konrad Stuhlmacher, BIM Content manager for Dr. Schiller & Partner, 14 April 2016, personal communication], the Germans are currently working on an integration of IFC and GAEB DA XML into a special, hybrid data format [16]. This “BIM-LV-Container” (LV for *Leisungsverzeichnis*, bill of quantities) would contain all the relevant information for tendering and communication between many actors, as is the case on the German construction market. It would be generated on the basis of the building model’s elements and updated as elements are modified during design process. The reason to keep a parallel file system is to avoid overloading IFC files for the sake of simplicity [16]. Parsing this data would amount to do what is currently done when parsing an IFC file at different stages of development.

A final note could be made on the harmonisation of the German, the Austrian and the Swiss data exchange formats. It is very unlikely to happen because of the intense effort that this would require [16]. It is possible, however, that an integrated format will be created alongside them or even replaces them in the long term. Maybe this is the goal of the “BIM-LV-Container” that is under development in Germany.

4.2 Information exchange patterns in the United Kingdom

The Brits do not produce bills of quantities/descriptive task lists in the way continental Europeans do. This might be due to the fact that in the English-speaking world, recording material quantities and costs is the matter of a specific profession, quantity surveyors.

However, Great Britain is taking BIM integration forward. Since April 4th, 2016, all public construction endeavours must comply with Level 2 BIM. This level of integration, as it is specified in the British standard PAS 1192-2:2013, requires among other things the “provision of a single environment to store shared asset data and information, accessible to all individuals who are required to produce, use and maintain it”. [17.] Furthermore, interoperability between design and analysis tools is underlined.

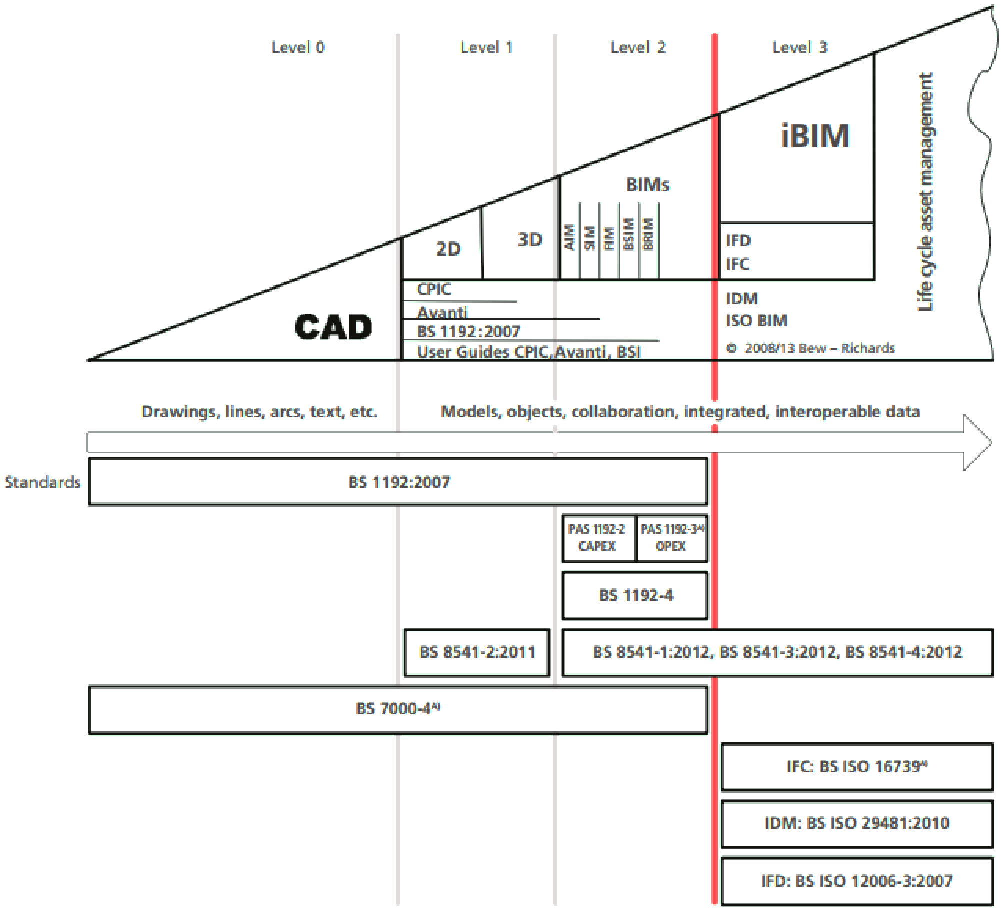

Figure 5. The BIM maturity levels as described in PAS 1192-2:2013.

Also, the use of building information modelling and of its open standard formats is more widespread in the United Kingdom than it is in of most continental European countries. Therefore, the construction industry there may resort directly to the possibilities proposed by deeper project integration and use the native BIM standards to carry and exchange information that elsewhere is displayed as a separate document or data. Figure 5 shows which British standards rule the Level 2 BIM [18].

In fact, as seen above, the IFC contains all the relevant information to produce a complete life-cycle assessment of the building. The only parameter to take into account for an LCA is the reliability of the information. At LOD 200, a component's characteristics are less clear than at LOD 300, but can still be used for an LCA. A way to get around the lack of information could be through extrapolation of environmental impact to room types and unit of surface area. This way, even in the absence of precise data about the component, abstract information would provide a preliminary range of the environmental impact of the building.

It is unlikely that IFC will ever integrate the complete environmental impacts of each building components. According to Panu Pasanen, the reason for this is the will to keep IFC files as light as possible, which is also the reason why Germans do not integrate the complete construction task descriptions into the classes. This means that it will still be necessary to establish a link between the model elements and environmental impact values.

An adequate approach to enable early LCA would be to be in touch with a competent LCA expert with adequate software capabilities as soon as possible once a construction project is started. The integration of an environmental expert into the design team might make this even easier. Alternatively, the use of an LCA plug-in in the drawing/modelling applications of the design team could instantly provide a draft LCA from the model with no further action.

Along with the IFC, two more data standard formats are used for information exchange among construction stakeholders, COBie and Uniclass. Both are currently developed and maintained by the British Construction Project Information Committee (CPIc), though COBie was originally designed and piloted by the US army [19].

The format Construction Operations Building Information Exchange (COBie) is used especially to ensure that the knowledge is transferred after construction to the facility management team at the Handover. The idea emerged in the United States in 2007, a few months before buildingSMART started to engineer the now international standard IFC. Now COBie has developed into a type of data that can be extracted from IFC or used to enrich IFC. [20.]

In its human-readable form, COBie is a spreadsheet where the data is organised by type on each sheet. The last British version of COBie is COBie UK 2012. Though use is intended for facility management purposes, the spreadsheet creation starts fairly early in the construction project stage and COBie data is delivered on a schedule "along with existing contract deliverables" [21]. In fact, COBie data is "dropped", or released, at least five times in the course of a project: [22]

Data Drop 1: the model represents requirements and constraints
Data Drop 2: the model represents outline solution
Data Drop 3: the model represents construction information
Data Drop 4: the model represents operations and maintenance information
Data Drop 5: the model represents post occupancy validation information

At drop 2 the available data becomes interesting for life-cycle calculations. It matches the stage 3 of the RIBA work plan, i.e. the developed design, which is early but reliable according to our previous findings. The COBie Data Drop guidelines specify that this drop can be used to ensure that "the interpreted design and specifications are consistent with the client brief in terms of function, cost and carbon" [22]. This explicit reference to environmental impact is corroborated by the presence of sheets such as "Component", "System" and "Assembly" featuring precise element names as well as columns for the values "length" and "area".

Name	ExtSystem	ExtObject	ExtIdentifier	SerialNumber	InstallationDate	WarrantyStartDate	TagNumber	BarCode	AssetIdentifier	Length	Area
Basic Wall:Generic Ext - 150mm:211829	Autodesk Revit Architecture 2012	IfcWallStandardCase	3cBcy7GEjBwPmXo$zkl3K4	n/a	n/a	n/a	211829	n/a	n/a		
Basic Wall:Generic Ext - 150mm:211830	Autodesk Revit Architecture 2012	IfcWallStandardCase	3cBcy7GEjBwPmXo$zkl3K7	n/a	n/a	n/a	211830	n/a	n/a	2700	
Generic Int D Cell Door:790 x 2110mm 3:790 x 2110mm 3:211815	Autodesk Revit Architecture 2012	IfcDoor	3cBcy7GEjBwPmXo$zkl3KM	n/a	n/a	n/a	211815	n/a	n/a		1
Generic Int DD:1810 x 2110mm:1810 x 2110mm:211798	Autodesk Revit Architecture 2012	IfcDoor	3cBcy7GEjBwPmXo$zkl3Kd	n/a	n/a	n/a	211798	n/a	n/a		1

Figure 6. Extract of the "Component" tab of a COBie spreadsheet at data drop 2.

Data drop 3 is equivalent to the technical design of the RIBA work plan, i.e. it is one project step further. There, too, the objective is to make sure that the developed design and specifications are in line with the client's requirements regarding the function of the building, its cost and its carbon performance [22]. Data still missing at drop 2 is likely to be present at drop 3, in the same way that information becomes more reliable with higher levels of development (LOD).

Parsing spreadsheets is already done by a few companies in the LCA software industry, and the support of COBie data is only a matter of filtering according to the relevant column and sheet labels. In fact, since COBie can be seen as the section of IFC dedicated to facility management, it amounts to parsing IFC.

A downturn of using COBie as a source is the likelihood that some important data is missing. COBie might contain objects and components that are not featured primarily in architectural and structural models, such as building service systems or electrical devices to be maintained and replaced in the course of the life-cycle of the building. But COBie data might also lack some parts of the structural model that are not relevant to the purposes of facility management like beams, slabs and reinforcement structures, which need no maintenance. Those elements are critical in a life-cycle analysis and ignoring them would produce an unacceptable result.

Aside from COBie, the CPIc also develops Uniclass, a classification system designed to order building information by class. The current system is called Uniclass 2015 [23] and features 11,872 entries divided in eleven groups called tables. The current Uniclass tables, with some examples, are listed below [24]:

1. Co – Complexes: A university campus
2. En – Entities: A teaching block
3. Ac – Activities: Lecturing
4. SL – Spaces/locations: Student bar
5. EF – Elements/functions: Roof
6. Ss – Systems: Timber roof framing
7. Pr – Products: Terrazzo tiles
8. Zz – CAD

Uniclass specifies the building component from a broad complex to a precise product. This is in line with the specifications of the standard PAS 1192, that states that "the Uniclass classification tables shall define the progressive maturity of the model from outline, spaces and volumes, to design elements and finally to products" [17].

In the event of imprecise element denomination, it is possible to rely on Uniclass in order to identify the element to a certain degree of precision depending on the advancement of the project. The National Building Specification provides the following example to make clear the organisation of systems in groups and sub-groups: [23]

- Ss_30: Roof, floor and paving systems
- Ss_30_10: Pitched, arched and domed roof structure systems
- Ss_30_10_30: Framed roof structure systems
- Ss_30_10_30_25: Heavy steel roof framing systems

The classification can be used to request information from building models. For example, a model element classified as Ss_30_10 can be recognised instantly as a "Pitched, arched and domed roof structure systems". Gross environmental impact values per square meter of roof of this type of structure would allow for the computation of a preliminary life-cycle assessment. Ss_30_20_10 on the other hand is the family code for "Board floor systems" and could be associated with average environmental impact values per surface unit of floor.

4.3 Information exchange patterns in France

Governments are recognising that policy and public procurement can act as a catalyst for the digital transition of the building industry. [25.] This is also true in France, where the public sector is encouraging the private one to adopt good practices by setting an example. [26.]

France has neither the standardised quantity take-off formats of the Germans nor the advanced BIM integration of the British. Currently a lot of Excel tables, portable document format (PDF) files and printed sheets are shuffled between the stakeholders during a construction process.

As bad as this sounds, this is not a threat to the French construction industry because it is centred on a few mammoth companies taking a lion's share of any significant construction project. Indeed, in 2011, three of the ten biggest European construction companies were French: Vinci (1), Bouygues (2) and Eiffage (6) [27]. Within the companies, information exchange is likely to occur according to standardised best practices agreed upon at either project or company level.

Legal incentives and requirements, however, aim at making the use of BIM more common [26], thereby introducing a situation like that in the United Kingdom, where information is centralised in the building information model through IFC.

In the past, there was a strong support throughout France for the use of the industrial standard EDIFACT, an international digital format developed within the United Nations. The standard never really took off in the construction industry and nowadays spreadsheets are the main way to produce and transfer bills of quantities at the various stages of the construction process. Spreadsheets are already supported in automated life-cycle analysis programmes.

The French hope to regain the time lost to their British counterparts in the field of BIM. Specialists are already drafting correspondences between the legal project stages according to the MOP law and the Levels of Development as specified by the AIA and the BIMForum [28]. A tentative correlation can be found in Figure 2. Adaptation of the current base missions will be necessary in the framework of BIM-based projects, and some new missions might even appear [28].

In this respect, if can be said that France is going the path that the United Kingdom chose a few years ago. Since there is no strong guild or professional union like the RIBA to organise the movement of the industry, the state will provide for the implementation of guidelines that it will set or borrow from abroad.

5 Conclusions

Regarding the deployment of new solutions for the automatisation of LCA, Germany offers promising prospects. There, bills of quantities provide a standardised, precise description of each building component, as well as the quantity of the component planned for the building. The detailed bills of quantities appear at the tendering phase, a fairly late stage of the building construction process, but they are likely to give very reliable results.

In Great Britain, the main obstacle to the automation of an early life-cycle analysis is the fact that quantity registration is not done by architects but by a particular profession, quantity surveyors. The component information is standardised and can be retrieved from other data than IFC, but the quantity take-off is still reliant on the building model. As of now, an IFC import for an automatised LCA is already a reality everywhere. It is not certain that integration and the support of a new data format would help increase the quality of LCA or make them possible earlier in the construction process. COBie and Uniclass can help in the identification of the nature of the building components, but they are a part of IFC rather than a parallel data format where data can be extracted from.

In France, the digital landscape is still so sparse that no real possibilities exist to extract building data at an early stage. No format is declared as standard and every company does things its own way. Custom spreadsheets can on an individual basis be analysed and parsed. However, it is likely that the major French construction companies have adopted best practices in this respect, which might amount to internal standards. Contact with them is needed to find this out.

Everywhere, the importance of building information modelling and of the industry foundation classes is growing. Understanding the structure of the industry foundation classes helps in a rapid and successful identification of building elements. In the United Kingdom, appending the Uniclass classification to every component of a building model could help bridge unclear denominations. Even if the exact name of the element is not known, pairing it preliminarily with an entry in the database that matches with the information available at that moment could bring LCA a step forward into the construction process.

As they will perform ever more LCAs in the coming years, LCA software companies could develop their own metrics, such as environmental impact ratios per unit of surface based on room type and equipment quality, in a way that is similar to building cost estimation. With such values, gross LCA could be possible at a conceptual stage and give indications to the design team. Research in this field is needed. LCA results from a scientific approach, and simplifying it too much might go against its purpose. It is necessary to find a balance between scientific accuracy and business-friendly simplicity.

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