Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector.

Desarrollo de un modelo de proceso para el uso holístico de la metodología BIM para la construcción sostenible en el sector público.

Entwicklung eines Prozessmodells für den holistischen Einsatz der BIM Methodik im nachhaltigen öffentlichen Bauen.

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Santander, Enero 2016
Dedication

Many thanks to you for supporting me.

[Signature]
Summary

The process of working with the BIM methodology is used around the world (wikipedia, 2015a), including within public construction sector (Porwal and Hewage, 2013). One advantage of working with the BIM methodology is that it produces improvements in the quality of the building, such as reductions in construction costs and time (Bryde et al., 2013; Yan and Damian, 2008). The BIM methodology offers an improved, continuous process of design, construction and operation, and consequently increased value creation across all the life cycle phases (Diaz, 2013). There is adequate awareness of the fact that financial support is required not just for the phases up to commissioning, but also for the operation of a building (Woodward, 1997). The design, construction and operation of buildings has fundamentally changed. Digital tools are now used by engineers, architects or specialist planners on a day-to-day basis. This change is bringing about improvements in information integration and in collaboration between all the parties involved. Information and media discontinuities are being significantly reduced. The results of this change and the use of the BIM methodology within the digital planning, construction and operation processes consequently reduce costs, ensure deadlines are met, and improve the quality of the building. In order for correct use to be made of the BIM methodology there should be a high density of information at the start of the planning process. Moreover, this information should be available in a verified, validated and reliable form. Verification and validation can be carried out on the basis of a sustainability certification system. This would provide a comprehensive foundation for all the subsequent processes and significantly improve them. What's more, the scope for influencing costs is greatest at the very start of the planning process: The costs of changes are lower than of those made in the project planning. Consequently, a high density of reliable information at the outset not only facilitates the holistic use of the BIM methodology in public construction sector. Further synergies result. Early planning decisions can be made. These increase the cost-effectiveness and quality of the building. One solution for fulfilling these constraints is requirement planning. The use of requirement planning enables a wealth of building information to be specified before the start of work stage 1.
Requirement planning is used for the methodical ascertaining of building information with the aim of raising quality and lowering costs (Deutsche Industrienorm, 1996). It is used in public construction sector in the form of DIN 18205. DIN 18205 is a translation of ISO 9699:1994 (International Standard, 1994). The procedural methods are defined on a national and international basis. DIN 18205 as well as ISO 9699:1994 form the basis of requirement planning. Requirement planning is consequently possible with either document. The DIN 18205 information provided through validation and verification at the start of the use of the BIM methodology is evaluated from a sustainability perspective, and it is also agreed with a large number of stakeholders. In many cases there is inadequate information available when the planning of construction work in public sector begins, despite the use of DIN 18205 (Hodulak and Schramm, 2011). This lack of adequate information has a negative effect on costs and deadlines, and on the quality of the building. The information deficiencies at the start of planning result from the fact that requirement planning according to DIN 18205 is not carried out, and made available, in an interoperable or a digital form. The DIN 18205 requirement planning information exists only in a decentralised, analogue form in physical documents. This leads to information and media discontinuities already occurring at the design stage. The level of integration of the information is consequently seriously deficient throughout the entire life cycle. The status quo shows that there is no holistic use of the DIN 18205 information in conjunction with the BIM methodology. Due to the features that have been mentioned, there is no use or validation of the DIN 18205 information in conjunction with the BIM methodology during the planning, execution or use phases. Requirement planning is however an important process throughout a building's life cycle. The aim of the work is to devise, produce and present a system for applying the BIM methodology in public construction sector in a way which takes account of sustainability aspects. The intention is to illustrate a holistic approach which takes account of sustainability as defined by the BNB (Bewertungssystem Nachhaltiges Bauen) and is based on the application of the BIM methodology in public construction sector. A new XML schema will be defined and developed which takes account of the requirements of DIN 18205.
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<td>ACEC</td>
<td>The Association of Consulting Engineering Companies</td>
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<td>AECOO</td>
<td>Architecture, Engineering, Construction, Owner and Operator industry</td>
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<td>AIA</td>
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<td>AIAB</td>
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<td>AP</td>
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<td>ASCII</td>
<td>American Standard Code for Information Interchange</td>
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<td>BBSR</td>
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<td>BNB</td>
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<tr>
<td>DBFMO</td>
<td>Design, Build, Finance, Maintain, Operate</td>
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<tr>
<td>dPoW</td>
<td>Digital Plan of Work</td>
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<td>EPIC</td>
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<td>GDP</td>
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<td>iBIM</td>
<td>integrated BIM</td>
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<td>ICE</td>
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<td>Information delivery manual</td>
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<td>IFD</td>
<td>International Framework for Dictionaries</td>
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<td>IR</td>
<td>Integrated Resources</td>
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<td>IU</td>
<td>Indiana University</td>
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<td>JIA</td>
<td>Japan Institute of Architects</td>
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<td>KEPCO</td>
<td>Korea Electric Power Corporation</td>
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<tr>
<td>KICT</td>
<td>Korea Institute of Construction Technology</td>
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<tr>
<td>KICTEP</td>
<td>Korea Institute of Construction and Transportation Technology Evaluation and Planning</td>
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<tr>
<td>KK-BIM</td>
<td>Building Information Modelling Coordination Committee</td>
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<td>KPX</td>
<td>Korea Power eXchange</td>
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<td>LEED</td>
<td>Leadership in Environmental and Energy Design</td>
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<td>LH</td>
<td>Land and Housing</td>
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<td>LI</td>
<td>Landscape Institute</td>
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<tr>
<td>MEP</td>
<td>Mechanical, Electrical, Plumbing</td>
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<td>MLIT</td>
<td>Ministry of Land, Infrastructure and Transport</td>
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<td>MLTM</td>
<td>Ministry of Land, Transport and Maritime Affairs</td>
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<td>MND</td>
<td>Ministry of National Defenses</td>
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<td>MVD</td>
<td>Model View Definitions</td>
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**List of abbreviations**

<table>
<thead>
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<th>Abbreviation</th>
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<tr>
<td>NBIMS</td>
<td>National BIM Standard-United States</td>
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<td>NBIS</td>
<td>National Institute of Building Sciences</td>
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<td>NBS</td>
<td>National Building Specifications</td>
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<td>Opex</td>
<td>Operational expenditure</td>
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<td>PAS</td>
<td>Public Available Standard</td>
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<td>PBS</td>
<td>Public Building Service</td>
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<td>PPS</td>
<td>Public Procurement Service</td>
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<td>PEre</td>
<td>Proportion of renewable primary energy</td>
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<td>PEtot</td>
<td>Total primary energy requirements</td>
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<td>PEnr</td>
<td>Non-renewable primary energy requirements</td>
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<td>PPP</td>
<td>Public Private Partnership</td>
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<td>PPS</td>
<td>Public Procurement Service</td>
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<td>RAIC</td>
<td>Royal Architectural Institute of Canada</td>
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<td>RCIS</td>
<td>Royal Institution of Chartered Surveyors</td>
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<td>RIBA</td>
<td>Royal Institute of British Architects</td>
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<td>RICS</td>
<td>The Royal Institute of Chartered Surveyors</td>
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<td>TC</td>
<td>Technical Committee</td>
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<td>SAM</td>
<td>Standard Approach of Modelling</td>
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<td>SC</td>
<td>Sub-committee</td>
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<td>SDAI</td>
<td>Standard DATA Access Interface</td>
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<td>SEI</td>
<td>Software Engineering Institute</td>
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<td>SINTEF</td>
<td>Foundation for Industrial and Technical Research</td>
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<td>SIS</td>
<td>Swedish Standards Institute</td>
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<td>SOA</td>
<td>Systems oriented architecture</td>
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<td>SRPA</td>
<td>State Real Property Agency</td>
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<td>SSC</td>
<td>Sector Command Center</td>
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<td>STEP</td>
<td>STandard for the Exchange of Product model data</td>
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<td>Totex</td>
<td>Total expenditure</td>
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<td>UKCG</td>
<td>UK Contractors Group</td>
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<td>UNEP</td>
<td>United Nations Environment Programme</td>
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<td>USACE</td>
<td>United States Army Corps of Engineers</td>
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<td>VDI</td>
<td>The Association of German Engineers</td>
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<td>WALLie</td>
<td>Wall Standards Exchanges</td>
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<td>WCS</td>
<td>World Conservation Strategy</td>
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## List of abbreviations

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<td>WFS</td>
<td>Web Feature Service</td>
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<td>WMS</td>
<td>Web Map Service</td>
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<td>WWF</td>
<td>World Wildlife Fund</td>
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<td>XML</td>
<td>Extensible Markup Language</td>
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<td>XSD</td>
<td>XML Schema Definition</td>
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1. Introduction

1.1 Foreword

In the following text the term Building Information Modelling is substituted by the abbreviation BIM. The term BIM methodology is also used. In order to define the benefits of BIM, the term Building Information Model will be applied as well.

1.2 History of building information modelling

From as early as the late 1970s through to the 1980s the terms "Building Product Models" (USA) or "Product Information Models" (Finland) were used in various academic texts to describe something akin to what is understood as BIM today. The procedures involved in "Building Product Models" were described as a new digital approach. The concept, the technology and the methodology is used in a way which takes account of all the building phases involved in producing a building (Eastman, 1999). In the field of informatics in civil engineering the general term "ICT" (Information and Computer Technology) was used for a long time for the digital erection of a virtual building. The next change in terminology was to the "Building Product Model" and the "Product Information Model". These terms were amalgamated into "Building Information Model" (Cerovsek, 2011, p. 226). The first recorded use of the term "Building Modelling" to denote what is now understood as BIM methodology was by Robert Aish at GMW Computers Ltd in 1986 (Wong et al., 2009a, p. 1). He describes the term "Building Modelling" as follows: 3D modelling, automatic extraction of drawings, intelligent parametric objects, relational databases, staggering of construction processes over time, etc. (Eastman, 2008, p. XII). According to Björk and Penttilä, the description of the technology encompasses 5 aspects: all the building information, the information requirements of all the parties involved, non-redundant, independent software, and independent formats (Björk and Penttilä, 1989). The term "Building Information Model" was first used by van Nederveen and Tolman in 1992 (van Nederveen and Tolman, 1992).
1.3 What is BIM? Characteristics and dimensions.

The characteristics of BIM are described in numerous documents. The perception, use, and discussion of the BIM process varies according to the type of building and formation of the specialist planner (Yan and Damian, 2008, p. 3). One reason for the differences in how it is perceived and used is the use of more than 3 dimensions. Spatial digital models are known to have 3 dimensions (3D) since they are geometrically defined using X, Y and Z axes. In the case of BIM, the spatial definition is supplemented with further information and / or characteristics through the use of supplementary dimensions. BIM is consequently not only a form of 3D modelling; depending on the application it can also represent 'nD' modelling (Smith and Tardif, 2012). Immediately before examining the characteristics of BIM and / or of the other dimensions, such as time, costs etc., a differentiation between 3D modelling and BIM is provided below. Then, individual BIM dimensions up to and including 'nD' are outlined.

Generally / traditionally the generating of 2D drawings and 3D models is possible in all commonly used CAD systems. 2D drawings are based, for example, on vectors combined with line types, layers, and colours etc. (Eastman, 2008, p. 12). 3D modelling supplements the functions of a 2D drawing with options such as surface shading, the production of 3D domains, or point clouds etc. (Yan and Damian, 2008, p. 2). The following explains which functions a 3D model does not provide, in contrast to a building information model (Eastman, 2008, p. 16). This explanation distinguishes 3D modelling from BIM:

- Models which only contain 3D information but not any object attributes are models which can be used for graphical visualisation but are not in any way object-oriented. They are used for visualisation, but they do not allow information to be integrated or construction analysis to be undertaken.

- Models which only define an image of the structure, but whose positioning or proportions cannot be altered because they do not
incorporate any parametric intelligence. This makes changes extremely labour-intensive and contributes to inconsistency and errors in the model.

- Models which are composite in nature and are accordingly made up of more than one 2D CAD reference files which are used to represent the building as a whole. It is impossible to ensure that the resulting 3D model is plausible, consistent, or that it contains the necessary intelligence in relation to the building contained in it.

- Models which allow changes in one view and do not automatically replicate them in all the relevant views. This leads to errors in the model, which may be hard to find depending on the level of complexity.

Collaboration involving the digital sharing of information in the architecture, engineering and construction fields was largely based on 2D drawings. The use of 3D modelling tools for visualisation and the developing of plans did not strengthen digital information sharing and collaboration (Singh et al., 2011, p. 134). BIM by contrast is a collaborative tool for use at all stages, from planning to construction as well as operation and subsequent management.

![Intelligent BIM](BIMCoder, 2014)
The need for BIM interoperability leads to a new level of collaboration being achieved, and its cooperative use eliminates planning errors and consequently increases productivity (Miettinen and Paavola, 2014, p. 84). BIM also makes it possible to change the parameters for object-oriented structural components such as walls, pillars and main beams etc., but also for objects such as tables, chairs, lights, etc. This enhances the functional intelligence of the components and objects (Lee et al., 2006, p. 759). The integrated intelligence reduces modelling errors and prevents subsequent technical defects during the construction phase (Eastman et al., 2004). Structural components and objects contain embedded information such as geometry, materials, assembly procedures, price, manufacturer, provider, and other additional associated information and specifications (Ibrahim et al., 2003, p. 547). In addition to the above points, BIM is also described by the following characteristics / dimensions (Azhar et al., 2008, p. 438)

- Visualisation: simple 3D renderings can be produced with little additional workload.

- Manufacturing / workshop drawings: once the model has been completed, prefabricated products can be manufactured.

- Plausibility check: fire brigade and other official bodies can use these models, e.g. for reviewing the escape routes etc.

- Analysis: the building information model can provide graphics for use in simulating breakdowns, leaks, evacuation plans etc.

- Facility management: the model can be used for servicing, renovation, and maintenance works.

- Cost estimates: BIM programs incorporate a quantities purchasing facility. Quantities of materials can be automatically called off.
Scheduling: a building information model can be used effectively to order materials and to draw up production and delivery schedules for all structural components.

Conflicts, disruptions and clash detection: all important systems can be visually checked for interference / clashes. It is, for example, possible to check whether pipes or cables clash with steel girders, ducts or walls (see Figure 5).

Fig. 2. Clash detection

Another issue is health and safety coordination at the construction site (Whyte, 2012, p. 6).

Each of these attributes represents a further dimension based on the 3D model. BIM is therefore described as an 'nD' modelling system (Bryde et al., 2013, p. 972).
The building information model provides a single, non-redundant and compatible information repository which supports planning, analysis, tendering and awarding, accounting, detailing, construction and process simulation (time, costs, etc.), as well as the creation, servicing and operation of a built structure. It contains machine-interpretable information for managing the data contained in it (McCuen, 2008).

Fig. 3. Possible dimensions of a building information model
(Dzambazova et al., 2009)

1.4 Object orientation within the BIM methodology

The great advantage of the BIM methodology is its object orientation (Hallberg and Tarandi, 2011). The use of object-oriented information as a consistent knowledge base makes it possible to structure the required characteristic values. One of the most important features of object orientation is the ability to
describe the available information in formal terms and to interrelate it (Björk, 1992, p. 173). In the construction field, the term object orientation is synonymous with BIM-based working. A digital structural component can consequently contain non-geometric information as well as geometric information (Ahn et al., 2010).

The elements used in a BIM system are digital structural components or objects which in reality represent one or more physical components of the building (Ahn et al., 2010). More detailed information is appended to the parts of a building, and typical objects within the building are depicted digitally (Mansperger et al., 2014, p. 238). In contrast to two- or three-dimensional digital planning, all the components such as walls, ceilings, stairways etc. are consequently regarded as related and object-oriented elements of the building under construction. The building information model accordingly represents not only a three-dimensional geometric description of the building under construction, it also contains typical components and objects including all their characteristics and technical specifications (May, 2013, p. 237). This makes the building information model a digital, object-oriented and intelligent knowledge base. It contains information
for a variety of users which is used for analysis, further processing and
decision-making, as well as for improving the entire process involved in
constructing a building (AGC, 2006). This happens at an early stage of the
planning process, and it is made available to all those involved in the
construction project for subsequent further processing (Albrecht, 2014, p. 102).
The value creation chain begins with planning and continues through execution
to the operational phase of the structure. The prerequisite for this value creation
chain is an interoperable building information model (Mansperger et al., 2014,
p. 238). Unlike the conventional 2D planning environment, this is able to depict
component-related material facts and structure-specific technical building
systems by means of its object-oriented intelligent representations. The digital,
virtual structure becomes a model which acts as a repository of numerous
relevant items of information for the construction and the subsequent life cycle.
This information is available to all the parties involved in the construction
project (Schlueter and Thesseling, 2009). The building information model
represents the geometric and non-geometric information relating to a building
(Cheung et al., 2012). Coherent working with the BIM at an early stage fosters
collaboration between the parties involved in the project so that duplication is
reduced. The early detection of errors that is facilitated by the building
information model makes the entire planning process more efficient (Azhar,
2011).

1.5 Big BIM and little BIM

The software systems that are available in the market and the associated
proprietary and non-proprietary interfaces make it possible to classify BIM
systems. A distinction is made between a little BIM and a big BIM solution
(Meyer-Meierling and Huber, 2015). Big BIM involves the interdisciplinary,
universal application of the BIM methodology. This constitutes open BIM. Use
of the BIM methodology is supported by non-proprietary interfaces, such as the
Industry Foundation Classes (IFC). Open big BIM consequently makes it
possible to work with various software products provided by a variety of
producers. The optimal software solution can be selected for the respective,
specialist application. Little BIM is generally used to describe working in
isolation within fewer phases or disciplines (Liebich, 2013a). The following explains the specific BIM classifications in greater detail.

- **little BIM:**
  Stand-alone solution within a specialist discipline with few project participants (phases)

- **big BIM:**
  Application of the BIM methodology across all the specialist disciplines and including all the parties involved in the project

A further distinction is made between

- **an open solution:**
  The use of various software packages with interlinking interfaces

  and a

- **closed solution:**
  Stand-alone solution using the software of a single producer

By extension, there are 4 categories of open and closed BIM (see figure 5).
Fig. 5. *big BIM and little BIM*  
(own Illustration according to Liebich et al., 2011):

- **Little closed BIM:**
  There is a stand-alone building information model, but only one for any given specialist discipline or any given phase. The BIM is only used within this field. There is no sharing of information. The software environment is proprietary, but there are no mutually agreed rules governing information sharing.

- **Little open BIM:**
  There is one building information model for any given specialist discipline or any given phase. The BIM is likewise only used for one field. The software environment is likewise proprietary, but non-proprietary interfaces like IFC are available (open BIM). Information can therefore be exchanged with other involved parties.
• **big closed BIM:**
  BIM is used across several specialist disciplines or phases. The software environment is proprietary, but there are mutually agreed rules governing information sharing. These may, for instance, be contractually agreed. The building information model is generally used as a coordination model, and it is linked to the respective specialist information via proprietary interfaces.

• **big open BIM:**
  BIM is used in an interdisciplinary manner across several specialist disciplines and/or phases. The various items of information are combined into a single building information model. There is a heterogeneous, and consequently non-proprietary, software environment in which the discipline-specific information is produced. All the parties involved have a holistic building information model at their disposal. Information sharing is governed by mutually agreed rules. Non-proprietary interfaces (IFC) are generally used.

### 1.6 BIM in construction in the public sector

The process of working with BIM in construction is used around the world, (wikipedia, 2015a) including within the public sector (Porwal and Hewage, 2013). One advantage of working with the BIM methodology is that it produces improvements in the quality of the building, such as reductions in construction costs and construction periods (Bryde et al., 2013; Yan and Damian, 2008). The BIM methodology offers an improved, seamless process of planning, building and operation, and consequently increased value creation across all the life cycle phases (Diaz, 2013). There is adequate awareness of the fact that financial support is required not just for the phases up to commissioning, but also for the operation of a building (Woodward, 1997). These phases can also be depicted using the BIM methodology.
The building stock of public institutions is very large. Statsbygg for example, the public institution in Norway which is responsible for the management of government-owned premises, manages 2.7 M sqm (Statsbygg, 2011). Senate Properties, the Finnish counterpart of Statsbygg, has a portfolio of 10,200 buildings covering a total floor area of 6.4 M sqm (Senate Properties, 2014). Buildings owned by public institutions such as municipal, regional or federal authorities consequently require financial subsidies during the construction phase as well as throughout their life cycle.

The larger the number of buildings, the greater is the financial expenditure for maintenance and operation. Furthermore, public institutions are obliged to adhere to specified time schedules, exacting quality standards, and tight budgets. Working with the BIM methodology in the public sector is intended to achieve quality improvements while simultaneously reducing costs (Porwal and Hewage, 2013). Moreover, the construction costs index has continually increased (Teicholz, 2014).
1.7 Sustainability in construction in the public sector

In many societies, continual economic growth is accompanied by increased awareness regarding environmental protection, and consequently a desire to use naturally-sourced resources. Construction plays an important role in this regard (Pandey and Shahbodaghlou, 2015): it is a primary consumer of raw materials and energy, both for the construction of buildings and during their operation (Kibert, 2011). 40% of total energy consumption within the European Union is accounted for by the buildings sector (EU, 2010). Up to three million tonnes of raw materials are needed for the construction of buildings each year (Graham, 2003). In 1994, at the first conference on sustainable construction, the following principle was therefore defined in relation to construction sustainability (Myers, 2013):

“...the creation and operation of a healthy built environment based on ecological principles and resource efficiency”
Since then, there have been various organisations which aim to define and apply sustainability strategies in construction for the public sector. These have produced sustainability certification systems. The Building Research Establishment created the British Research Establishment Environmental Assessment Model (BREEAM). In the United States, the Leadership in Environmental and Energy Design (LEED) programme forms the basis of assessment. (Pandey and Shahbodaghlo, 2015). In Germany, the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) in collaboration with Deutschem Gütesiegel für Nachhaltiges Bauen e. V. (the association managing the German sustainable building quality mark), have created the Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB, German Sustainable Building Council) and the Bewertungssystem Nachhaltiges Bauen (BNB, Sustainable Building Evaluation System) for federal buildings (BMUB, 2013a).

1.8 Problem statement

Buildings require financial subsidies not only during the planning phase but also during the construction and operation (see Figure 6). Depending on the quality of the design process, difficulties arise in the fulfilment of the time schedules. This leads to costs uncertainties and quality defects during the subsequent construction and / or operation process. The design, construction and operation in civil engineering has fundamentally changed. Digital tools are now used by engineers, architects or specialist planners on a day-to-day basis. This change causes improvements in the consistency of information and cooperation between all stakeholders. Information and media discontinuities can be significantly reduced. The results of this change, through the application of the BIM methodology in the design, construction and operation process, is therefore reducing costs, ensuring time schedules and increasing the quality of the work. For the correct application of the BIM methodology there should be a high density of information at the start of a design process. Moreover, this information should be available in a verified, validated and reliable form. Verification and validation can be carried out on the basis of a sustainability certification system. This would provide a solid foundation for all the subsequent processes and sig-
significantly improve them. What's more, the scope for influencing costs is greatest at the very start of the planning process: the costs of changes are lower than of those made in the course of planning. Consequently, a high density of reliable information at the outset not only facilitates the holistic use of the BIM methodology in public construction sector. Further synergies also result as planning decisions can be taken at an earlier stage. This increases the cost-effectiveness and quality of the building (see Figure 8).

Fig. 8. Financial consequences of planning decisions
(own illustration according to Möller and Kalusche, 2013)

A high level of information density and early planning decisions contribute to the holistic use of the BIM methodology. This is because the greater the density of the validated and verified reliable information at the beginning of the digital planning process is, the more detailed the virtual mapping of the building through the use of the BIM methodology – and the resolution of technical issues – can be (Eastman et al., 2011, p. 163).

One solution for the fulfilment of the demands is the requirement planning. The use of the requirement planning enables the wealth of the building information to be specified before the start of work stage 1. Requirement planning is used for the methodical ascertaining of building information with the aim of raising
quality and lowering costs (Deutsche Industrienorm, 1996). It is used in public construction sector in the form of DIN 18205. The methodical ascertaining through the DIN 18205 information provided building information, which is validated and verified at the start of the use of the BIM methodology and more important evaluated from a sustainability perspective. Moreover it is also agreed with a large number of participants. In many cases there is inadequate information available when the planning of public construction sector work begins, despite the use of DIN 18205 (Hodulak and Schramm, 2011).

The Federal Budgetary Code (BHO) states that financial approval for a Federal building project may only be given, once certain parts of the requirement planning have been completed. This includes completing the estimation of costs. The financial resources for constructing the building are not approved before this has been done (cf. §24 BMJV, 1969; BMUB, 2015, p. 34). Nonetheless, there is no cost certainty in the field of public construction sector. This lack of cost certainty also causes reductions in quality as well as time scheduling problems. The information deficiencies at the start of planning are due to the fact that requirement planning according to DIN 18205 is not carried out and made available in an interoperable or a digital form. The DIN 18205 requirement planning information exists only in a decentralised, analogue form.

Fig. 9. Status quo in requirement planning
in physical documents. This leads to information and media discontinuities already occurring at the design stage. The level of integration of the information is consequently seriously deficient throughout the entire life cycle. The status quo shows that there is currently no holistic use of the DIN 18205 information in conjunction with the BIM methodology. Due to the features that have been mentioned, there is no use or validation of the DIN 18205 information through use of the BIM methodology during the design, construction or operation phases. Requirement planning is however an important process throughout a building's life cycle.

1.9 Investigations, issues and goal

The aim of this work is to devise, produce and present a system for applying the BIM methodology in public construction sector in a way which takes account of sustainability aspects. The purpose is to illustrate a holistic approach which is based on sustainability as defined by the BNB and the application of the BIM methodology in the public construction sector. A new XML schema is defined and developed which takes account the demands of DIN 18205. The XML schema that is implemented in this thesis acts as a container for the model of the DIN 18205. This model presents all the DIN 18205 demands in a structured, digital format. An assessment and verification of the building information, which is indispensable for the consistent application of the BIM methodology will be made possible by the the model of the DIN 18205. Furthermore, the methodological findings according to DIN 18205 can be evaluated in terms of sustainability by using the BNB. The quality of the entire process, as design, construction and operation is consequently enhanced and secured. For the first time, all the DIN 18205 building information is available in a digital, interoperable and integrated environment. Quality, costs and scheduling agreements relating to the building are preserved. Media discontinuities within the requirement planning process are eliminated through the use of the model for the DIN 18205 container. The correct, digital application of DIN 18205 together with the BIM methodology leads to consistency in design, construction, and operation. The interoperability,
Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

integratedness and scalability of the new XML schema creates a new type of digital process within the construction field in the public sector.

In this context, the use of the BIM methodology in the public construction sector around the world is analysed. Existing investigations show that the BIM methodology is not used in an integrated, holistic manner (Diaz, 2014). Thus will be examined in greater detail how the BIM methodology is applied within the public construction sector in various countries. The focus will be on its actual development status. Based on existing guidelines the implementation of the BIM methodology is presented and demonstrated. The BIM maturity models that exist around the world are also described. BIM maturity models provide information about the degree of implementation of the BIM methodology. In addition, the interoperable interface IFC (Industry Foundation Classes) for data exchange is also examined. Then, systems for assessing sustainability are presented and analysed. The findings of these investigations are used to highlight an approach which holistically combines the BIM methodology with sustainability within public construction sector.
1.10 Presentation of the chapters

The following illustration shows the structure of the individual chapters. They are then described textually.

In Chapter 1 the semantic of building information modelling (BIM) is defined. An outline of the history of the technology is provided. Following on from this, object orientation is explained and a technological definition of BIM is provided. This is done through a comparison with conventional 3D models. In order to describe the full functionality of a BIM, the further dimensions in addition to 3D are listed. The terms 'big' and 'little' as well as 'open' and 'closed' BIM are explained in order to provide a better understanding of interoperability. The
application of BIM in public construction sector is described as well as sustainability in construction.

In Chapter 2 the application of BIM in public construction sector is analysed. Since the progress made in applying the BIM methodology in public construction sector varies, the level of progress around the world is documented based on mandatory or recommended guidelines. An outline is given of the existing specifications, standards and manuals relating to public construction sector. In addition, the chronological development of guidelines or bodies of rules is shown. Parallel or new developments or enhancements, especially guidelines or bodies of rules which are derived from public construction sector and are developed by other non-governmental and / or not-for-profit organisations, are also mentioned. These are regarded as a supporting development.

In Chapter 3 the findings of the analysis are summarised. Based on these findings, the subsequent analysis, and consequently the subsequent chapters, can be outlined.

In Chapter 4 the maturity models are used for measuring the level of implementation of the BIM methodology in an organisation or company. This chapter provides an overview of how the BIM maturity level is measured in various countries.

In Chapter 5 interoperability within the construction sector is explained, as well as the development of the interoperable interface IFC. This interface forms the basis of an exchange format that functions worldwide on a interoperable basis.

In Chapter 6 sustainability within the construction sector is defined. Existing sustainability certification systems around the world are named, and those which are most widely used are described in more detail. This is accompanied by a more detailed analysis of the BNB sustainability certification system, and in particular of process quality.
In Chapter 7 an interoperable, digital method of using requirement planning in conjunction with building information modelling and the BNB sustainability considerations is outlined. DIN 18205 is implemented and digitally integrated within in a new XML (extensible markup language) schema. The XML schema should be regarded as a specific suggested approach for the holistic use of the BIM methodology in sustainable construction in the public sector.

In Chapter 8 overall conclusions are drawn and the outlook regarding further research is summarised.
2. Analysis of the international application of the BIM methodology in public sector

The progress made in applying the BIM methodology in the public construction sector varies around the world. In some countries there are mandatory specifications and standards which define working with the BIM methodology and specify its use by public bodies and / or for government projects. In other countries, working with the BIM methodology is recommended but not mandatory.

In this chapter the application of the BIM methodology in public construction sector around the world is analysed. An outline is given of the existing specifications, standards and manuals relating to public construction sector. In addition, the chronological development of guidelines or standards in the following countries is shown. Parallel or new developments or enhancements, and guidelines or standards which are derived from public construction sector and have been developed by other non-governmental and / or not-for-profit organisations are also mentioned. These are regarded as a supporting development. Finally, the findings are summarised.

2.1 Selection of countries for the analysis

Two sources were regarded as providing a suitable basis for an international analysis of the countries where the use of the BIM methodology is mandatory. They were used to specify the countries where the BIM methodology is applied. These sources are a survey by the Autodesk University and secondly a variety of market research reports produced by McGraw Hill. Both sources evaluate the application and extent the usage of the BIM methodology from an economic perspective. From this point of view, conclusions regarding the basic usage of the BIM methodology is feasible. It may be assumed that the BIM methodology is also used in the public construction sector. The McGraw Hill reports examine the United States (McGraw Hill, 2012), Australia and New Zealand (McGraw Hill, 2014a) as well as Japan, South Korea, Canada, Great Britain, France,
Germany and Brazil (McGraw Hill, 2014b, p. 10). The Autodesk University
survey contains graphics for Sweden, Italy, Spain, Denmark, Norway, the
Netherlands and Finland as well as China, Singapore and Hong Kong (Hoffer,
2012, p. 8,10; Kiviniemi, 2013, p. 67). The specific McGraw Hill reports are
named below.

- The Business Value of BIM in North America, Multi-Year Trend Analysis
  and User Ratings (2007-2012)
- The Business Value of BIM in Australia and New Zealand, How Building
  Information Modeling is Transforming the Design and Construction
  Industry
- How Building Information Modeling is Transforming the Design and
  Construction Industry, How Building Information Modeling is
  Transforming the Design and Construction Industry

The aim of the McGraw Hill reports is to show the business value of BIM in the
specified countries and to provide information on the changes that BIM has
brought about in the construction industry.

The next graphic shows the result of the Autodesk University study. The
assigning of the diagram axes is according to an independent Autodesk
University method of classification. The classification should not be related to
the BIM maturity models described in Chapter 4. The Autodesk University study
and the McGraw Hill reports were used only for selecting the countries. Further
sources were used for for the resulting analysis that will be shown in the
following chapters.

The Autodesk University survey shows the project-based adaptation of BIM. It
also contains graphics showing the bodies of rules that exist in the respective
countries and the associated contractual agreements.
The countries shown in the following table are derived from the McGraw Hill reports and the Autodesk University survey. The countries are arranged in alphabetical order.

<table>
<thead>
<tr>
<th>Country</th>
<th>Autodesk University survey</th>
<th>McGraw-Hill reports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Brazil</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Denmark</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Finland</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Great Britain</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Canada</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

*Fig. 12. BIM policy stage by adoption rate*
Both above mentioned investigations are based on financial considerations, as already described. The financial indicator refers to the application of BIM in the countries.

The countries in the following chapters are not arranged in alphabetical order as they are in Table 1. The following chapters are arranged by continents. The analysis of the countries is carried out in the following order:

- East Asia
  - China, Hong Kong, Japan, Singapore and South Korea.
- British Isles
  - United Kingdom
- America
  - Brazil, Canada and United States
- Northern Europe
  - Denmark, Finland, Sweden and Norway
- Central and Southern Europe
  - France, Germany, Italy, the Netherlands, and Spain
- Oceania
  - Australia and New Zealand

<table>
<thead>
<tr>
<th>Country</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>New Zealand</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Netherlands</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>North America</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Norway</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Singapore</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>South Korea</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

_Table 1. Autodesk University survey and the McGraw Hill reports_
2.2 East Asia

2.2.1 BIM in China

The BIM methodology was promoted by Autodesk in China as long ago as 2004 (Autodesk, 2012, p. 1). In 2007 the industry-standard JG/T 198-2007 building information model platform was set up (Zheng, 2014, p. 6). In addition, in 2008 a further platform standard was created based on the IFC (Wang et al., 2013, p. 990).

2.2.1.1 Status quo in public construction sector

In the 11th National Five-Year Plan (2006-2010) it was suggested that IFC should be used as a collaborative interface. IFC2x was declared to be the national standard (Kiviniemi, 2006, p. 25). China supports IFC-based open BIM (Zhang et al., 2014). The introduction of national BIM standards was incorporated into the 12th National Five-Year Plan (2011-2015) (CIC, 2013a, p. 7; Kiran, 2014). China stated that it would develop 2 national BIM standards: *one covering the delivery of information, and the other coding and classification* (buildingSMART, 2013). In 2013 the China BIM Union was founded. This is an organisation for developing and promoting Chinese BIM technology. It is a technical committee of the China Association for Engineering Construction Standardization (ZES). This project is supported by the Ministry of Science and Technology (China BIM Union, 2013).

2.2.1.2 Peripheral developments

In 2009 the first investigations into the China BIM Standard (CBIMS) began at Tsinghua University. This involved creating a basic structure for developing the CBIMS (Wang et al., 2013, p. 990). Unlike in Hong Kong, the development of BIM is driven not by the government but by the university institutions and by research and development organisations (Gao, 2013).
2.2.2 BIM in Hong Kong

2.2.2.1 Status quo in public construction sector

Hong Kong’s Housing Authority (HA) is a statutory body. Since 2009 it has been developing various standards and guidelines for the successful implementation of BIM (HA, 2014). Specifically these are the following documents:

- BIM Standards Manual
- BIM User Guide (Part I)
- BIM User Guide (Part II)
- BIM Library Components Design Guide
- BIM Library Components Reference
- Standard Approach of Modelling (SAM) for Creating Building Information Structural Model

In 2006, HA began to use BIM in social housing construction projects. BIM was applied in various project phases, from feasibility study to the construction phase. This enabled experience of the actual implementation of BIM to be gained (HA, 2014). HKBIM (The Hong Kong Institute of Building Information Modelling) was established in 2009 (Owen and Prins, 2010, p. 291). In 2013 HKBIM published the BIM Project Specification. This document constitutes the general guidelines for the uses of BIM in a construction project. (HKIBIM, 2013). The Hong Kong Construction Industry Council (CIC) has set up a working group in order to develop a roadmap for successful BIM implementation (Wong, 2013, p. 3). The members of the working group are shown in the following table.
The Hong Kong government takes a proactive role in implementing the BIM methodology. Various steps have been specified for managing this implementation. They are shown in the following diagram.

Table 2. Working group in Hong Kong

<table>
<thead>
<tr>
<th>Type</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public authorities</td>
<td>Hong Kong Institute of Surveyors</td>
</tr>
<tr>
<td></td>
<td>Hong Kong Institution of Engineers</td>
</tr>
<tr>
<td></td>
<td>Hong Kong Institute of Architects</td>
</tr>
<tr>
<td></td>
<td>Hong Kong Institute of Building Information Modelling</td>
</tr>
<tr>
<td></td>
<td>The Association of Consulting Engineers of Hong Kong</td>
</tr>
<tr>
<td></td>
<td>The Association of Architectural Practices</td>
</tr>
<tr>
<td></td>
<td>British Chamber of Commerce</td>
</tr>
<tr>
<td></td>
<td>Hong Kong Institute of Utility Specialist</td>
</tr>
<tr>
<td>Contractors</td>
<td>Hong Kong Construction Association</td>
</tr>
<tr>
<td></td>
<td>Hong Kong General Building Contractors Association</td>
</tr>
<tr>
<td></td>
<td>The Hong Kong Federation of Electrical and Mechanical Contractors</td>
</tr>
<tr>
<td>Academic</td>
<td>University of Hong Kong</td>
</tr>
<tr>
<td></td>
<td>The Chinese University of Hong Kong</td>
</tr>
<tr>
<td></td>
<td>The Hong Kong Polytechnic University</td>
</tr>
<tr>
<td></td>
<td>Institute of Vocational Education</td>
</tr>
</tbody>
</table>
2.2.2.2 Peripheral developments

The CIC is a forum which brings together 24 members from industry, the university sector and the government (CIC, 2012), and it either develops guidelines such as the CIC Building Information Modelling Standards Draft 6.0 (HKBIM, 2015) for promoting the use of BIM in Hong Kong. The Polytechnic University in Hong Kong teaches the use of BIM. The education is geared more to the needs of project managers than those of architects (Andy K D Wong et al., 2011, p. 473). The course content is shown in the following table (Andy K D Wong et al., 2011).

<table>
<thead>
<tr>
<th>Level</th>
<th>Discipline</th>
<th>Year</th>
<th>Subject</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher Diploma</td>
<td>Building Technology and Management</td>
<td>1</td>
<td>Information and Data Analysis</td>
<td>4 weeks</td>
</tr>
<tr>
<td>Undergraduate</td>
<td>Building Engineering and Management Surveying</td>
<td>1</td>
<td>Building Information Modelling</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>Engineering Contract Procedure</td>
<td>1 week</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>Computerized Construction Production</td>
<td>1 week</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>Management</td>
<td>1 week</td>
</tr>
</tbody>
</table>
The AIAB (Autodesk Industry Advisory Board) which was founded in 2005 is also an organisation which aims to promote the use of BIM in Hong Kong (AIAB, 2014; Wong et al., 2009a, p. 4).

2.2.3 BIM in Japan

2.2.3.1 Status quo in public construction sector

In 2009 the Ministry of Land, Infrastructure and Transport (MLIT) published the National BIM Roadmap. In 2010 the first project using BIM was commissioned by the MLIT, and further investigations were commissioned at the same time (Lee, 2012, p. 4). In 2014 the MLIT published the BIM Guideline for Governmental Buildings (buildingSMART, 2014). The use of BIM in the construction field in public sector is not mandatory (Yoshihiko, 2014, p. 2).

2.2.3.2 Peripheral developments

In 2012 the Japan Institute of Architects (JIA) published its BIM guidelines (Shiokawa, 2013, p. 18). Further guidelines, e.g. for working with IFC based, open BIM are being developed (Karkshøj, 2013, p. 4).

2.2.4 BIM in Singapore

2.2.4.1 Status quo in public construction sector

In Singapore, the Building Construction Authority (BCA) has taken up the subject of BIM. As long ago as 1995 the BCA developed an automated internet platform for the digital design control of digital 2D plans which was called CORENET (COnstruction and Real Estate NETwork). In 1998 it was renamed...
CORENET Systems, and since then it has been used to analyse 3D IFC files (Eastman et al., 2009, p. 1013) It is used as a web-based submission and review system for digital building plans (Choi et al., 2012, p. 144). The aim of CORENET was to integrate the basic processes, such as design and the awarding of contracts as well as building and operation. At that time, a review was undertaken of regulatory requirements within digital planning. Artificial intelligence was used for this (Khemlani, 2005). Furthermore, in 2010 BCA specified a roadmap for the construction industry. The aim is to achieve a BIM implementation level of 80% in public construction sector by 2015 (BCA, 2013a, p. 1). In 2012 BCA published the first version of the Singapore BIM Guide (BCA, 2012a). Version 2 followed in 2013 (BCA, 2013b). Both versions are intended to describe the requirements in terms of processes, skilled labour, and other people involved in a construction project where BIM is used (BCA, 2013b, p. 1, 2012a, p. 1). On the website http://www.corenet.gov.sg (last visited 07.04.2015) which is supported by the Ministry of National Development there is a facility for downloading templates for the Revit, ArchiCAD, Tekla Structure und Bentley programs for the various fields of activity (architecture, statics or MEP, HVAC). In May 2012 and August 2013 bodies of rules for the use of BIM were published. These describe the duties of the responsible planners, and they provide general support for the development of a "BIM execution plan" (BCA, 2013b). The electronic submission of the architectural model for projects of over 20,000 sqm on a basis of a building information model has been mandatory since 2013 (BCA, 2013c, 2012b). Since 2014 the electronic submission of engineering models on a basis of a building information model has also been mandatory for projects of over 20,000 sqm. As from July 2015 the size threshold is being reduced to 5,000 sqm, and the usage of BIM is being extended to all work stages in a construction project (BCA, 2013a, p. 2; Staub-French et al., 2011).
2.2.4.2 Peripheral developments

Together with buildingSMART, the BCA is developing a library of objects in the construction field. The university in Singapore provides BIM workshops and seminars. Furthermore, a fund has enabled the construction industry to cover the training, software and hardware costs involved in converting the planning procedure to BIM (Khemlani, 2012).

2.2.5 BIM in South Korea

2.2.5.1 Status quo in public construction sector

The use of BIM in the field of public construction sector is mandatory in South Korea. In 2012 the Public Procurement Service (PPS) of the Republic of Korea decided to make the use of BIM mandatory for all projects undertaken by the government with a value of over US $ 44.0 M. In 2013 the threshold was lowered to $ 27.6 M and made applicable to all public sector projects. BIM will become fully mandatory in all public sector projects in 2016 (Yum, 2013). The PPS is equivalent to the GSA in the United States (Kim, 2012). The use of BIM is based on the open BIM methodology and the IFCs. The existing bodies of rules are listed in the following table, arranged by type (G. Lee, 2014):

<table>
<thead>
<tr>
<th>Type</th>
<th>Organization</th>
<th>Guides</th>
</tr>
</thead>
<tbody>
<tr>
<td>National domain-specific</td>
<td>MLTM (Ministry of Land, Transport and Maritime Affairs)</td>
<td>- 2010: National BIM Roadmap</td>
</tr>
<tr>
<td></td>
<td></td>
<td>National Architectural BIM Guide</td>
</tr>
</tbody>
</table>
Table 4. Bodies of rules in South Korea

<table>
<thead>
<tr>
<th>Public organizations</th>
<th>Research &amp; Development</th>
<th>Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPS (Public Procurement Service)</td>
<td>KICT (Korea Institute of Construction Technology)</td>
<td>KPX (Korea Power eXchange)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Digital Broadcasting Contents Center</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- 2010: First PPS Open BIM based Turnkey (Design Build) project</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KEPCO (Korea Electric Power Corporation)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- 2011: BIM Design Competition Guideline</td>
</tr>
</tbody>
</table>

2.2.5.2 Peripheral developments

In 1998 the Korean government standardised a procedure with the aim of improving the efficiency and precision of the planning approval procedure. This standard was transposed into the SEUMTER web-based information system which was developed in 2008 as part of a research project. It is also planned to extend the SEUMTER system. The intention is that in future, digital building information will be subjected to a review process, and 3D building models will be able to be reviewed according to the current Korean planning and building laws (Karam and Jungho, 2014).
2.3 British Isles

2.3.1 BIM in Great Britain

2.3.1.1 Status quo in public construction sector

The National Building Specifications (NBS) set bodies of rules for architects and other people involved in construction (Whyte, 2014). NBS is an independent institution which is part of the Royal Institute of British Architects (RIBA). Another public body which deals with the subject of BIM in Great Britain is the BIM Task Group. The BIM Task Group is funded by the British government (HMG) and administered by the Cabinet Office. The Cabinet Office is a central authority within the British government which is responsible for supporting the Prime Minister and Cabinet. In October 2010 the British government's chief construction sector adviser pointed out that BIM could play an important role within public construction sector (Race, 2013). In May 2011 the Cabinet Office published the Government Construction Strategy. This emphasises that at the latest by 2016 working at BIM Level 2 with the use of complete, collaborative 3D BIM (cf. section 4.2.3) should be made obligatory for public sector construction projects. Furthermore, all the information that is required for this should be made available in electronic form (Cabinet Office, 2011, p. 14). According to the report, all the parties involved in construction must work using a single information source. The lack of compatible systems, standards and protocols, and the differing requirements of customers and designers, lead to mistakes being made. In addition, this document contains an action plan describing the possible step-by-step adaptation of 3D BIM, and it proposes an implementation plan with milestones as well as the creation of a group of experts (Cabinet Office, 2011, p. 34). In 2012 a further Government Construction Strategy was published. This reported that the group of experts established in 2011 was proposing to establish a programme of trial projects in order, among other things, to test the BIM approach. The Royal Institution of Chartered Surveyors (RCIS), the British professional body for property experts and surveyors, has also been involved in establishing BIM since 2011. In addition, the Royal Institute of British Architects (RIBA) and the Construction Industry Council (CIC) have drawn up a Publicly Available Standard (PAS) 1192-2:2013. This focuses in particular on the graphical and non-graphical
information which is amassed during the planning and the construction phase (BSI, 2013a). A mutual agreement has been entered into with buildingSMART US in order to develop a national BIM standard according to the principles of interoperability with the aim of achieving the future BIM Level 3 (HMG, 2015, p. 32). The group of experts that was formed in 2011 has now been renamed into BIM Task Group (Cabinet Office, 2012, p. 16). The following graphic shows the achievement of BIM Level 2 according to the UK BIM Task Group roadmap (Philp, 2013).

Fig. 15. Strategy of the BIM Task Group

In 2013 the CIC published the BIM Protocol with the assistance of the BIM Task Group. This can be used for all the contracts that are commonly used in the construction sector, and it supports working at BIM Level 2 (CIC, 2013b). In 2014 NBS published a national, online library of BIM objects, and it simultaneously provided the BIM Object Standard for construction industry suppliers: this is a standard for creating library objects for the architecture, engineering and construction fields (NBS, 2014a). The standardization development of these bodies of rules began as long ago as 2011.
The standardization includes the following bodies of rules: (BIMTalk, 2014; Konrad Stuhlmacher, 2014; Waterhouse, 2011):

- BS 8541-1 (Identification and grouping)
- BS 8541-2 (Recommended 2D symbols of building elements for use in Building Information Modelling)
- BS 8541-3 (Shape and measurement)
- BS 8541-4 (Attributes for specification and simulation)
- BS 8541-5 (The sharing of sub-models representing combinations of components and spaces)
- BS 8541-6 (currently being written: Covers product declarations - the sharing of data expected from product declarations, labelling and environmental tables)

Apart from the above shown bodies of rules, the following standards exist in relation to BIM (BIMTalk, 2014):

- BS 1192:2007 (Collaborative production of architectural, engineering and construction information)
- PAS 1192-2:2013 (Specification for information management for the capital / delivery phase of construction projects using building information modelling.)
- PAS 1192::3:2014 (Specification for information management for the operational phase of assets using building information modelling)
- PAS 1192::4:2014 (Fulfilling employers' information exchange requirements using COBie)

Innovate UK has awarded a prize of £1.0 M to NBS for developing a usable BIM Toolkit which is to be made available to the construction industry free of charge. This was released in April 2015 and it serves as a web-based review and validation system for all public sector projects. The BIM Toolkit provides step-by-step assistance with the defining, managing, developing and provision of information – alongside the associated responsibilities – in every phase of a
Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

2 Analysis of the international application of the BIM methodology in public sector

building's life cycle (CIOB, 2015). This is done by incorporating the Digital Plan of Work (dPoW). The current BIM level is validated based on the mandatory submission of projects basis on a BIM Level 2 from 2016 onwards for all public construction projects. The BIM Toolkit still includes over 5,000 construction objects (Lockley et al., 2015).

From 2016 all public construction projects must be contractually agreed using BIM Level 2. From 2016 up to 2025 the British government wants to move towards Level 3 in collaboration with the industry (HMG, 2013, p. 60).

The B/555 Roadmap was published in 2013 and 2015 by the British Standards Institution (BSI), and specifically by Committee B/555 on Construction design, modelling and data exchange (BIMTalk, 2013; BSI, 2015a). The 2013 roadmap sets out the path to achieving BIM Level 2 (BSI, 2013b; buildingSMART United Kingdom and Ireland, 2014).

2.3.1.2 Peripheral developments

In 2009 the AEC (UK) BIM Standard Committee published file templates for various BIM software packages, such as Revit, Bentley and ArchiCad (AEC (UK) CAD Standard, 2009). This was followed by the AEC (UK) BIM Protocol in 2012. It contains platform-independent descriptions and program-specific supplements (for Revit and Bentley) for collaborative working with BIM (AEC (UK), 2012).

In 2010 the BIS (Department for Business, Innovation and Skills) Working Group was established. The members of BIS include representatives of both private and public construction sector. It comprises various government institutions, universities, construction companies, and software firms. In March 2011 the Working Group published 'A report for the Government Construction Client Group', which is also referred to as the 'BIM Working Party Strategy Paper' or simply 'BIS BIM Strategy'. The aim of the report was to inform the Construction Client Group about progress and results (BIM Industry Working Group, 2011). The Construction Client Group is the centrepiece of Constructing
One of the tasks assigned to the programme of trial projects that was established in 2011 (group of experts, Government Construction Strategy) was to investigate the COBie interface that was developed by the United States Army Corps of Engineers (UASCE) (see 2.4.3.2). This investigation established that, unlike in the United States, this interface can be used not only for exchanging information during the operation of a building, but also during the construction phase (Malleson et al., 2012, p. 6). The technology has been adapted and since then it has been operated in England under the title COBie 2012 UK.
2.4 America

2.4.1 BIM in Brazil

2.4.1.1 Status quo in public construction sector

In 2013 AsBEA (Brazilian Association of Architecture Firms) published the GUIA AsBEA Boas Prácticas em BIM (guidelines on good BIM working practices) (AsBEA, 2015). AsBEA was supported by the Conselho de Arquitetura e Urbanismo da Brasil (The Brazilian Association of Architecture and Urban Planning). The body responsible for drawing up the guidelines document was GTBIM, a federation of 11 architects (GTBIM, 2013). The guidelines are available in Portuguese. Further bodies of rules relating to BIM are to follow (AsBEA, o. J.). In addition, there is a body of rules relating to CAD which deals with the issue of interchangeability in relation to digital projects (AsBEA, 2011).

2.4.1.2 Peripheral developments

The BIM Network (Redes BIM Brasil) was created in 2008 as the result of a research project carried out at Brazilian universities. The aim of it was to create a network of cooperation in which the integration and interoperability of digital systems could be discussed in relation to BIM and IFC in the construction sector. The research project was brought to an end in 2013 (Rede BIM Brasil, 2008).

Further bodies of rules for the construction industry can be found on the Manuais de Escopo website (scope manuals). These are generally construction industry manuals. The operators of the site are the most important professional bodies in the construction industry (Escopo, 2015).
2.4.2 BIM in Canada

2.4.2.1 Status quo in public construction sector

The Institute for BIM in Canada (IBC) which was founded in 2010 is responsible for the development of BIM (IBC, 2015a). The individual members of the IBC are as follows (IBC, 2015b):

- the Association of Consulting Engineering Companies (ACEC),
- the Canadian Construction Association (CCA),
- the Construction Specifications Canada (CSC), and
- the Royal Architectural Institute of Canada (RAIC).

2 packages relating to the use of BIM can be found on IBC's website. The Design Development Phase Toolkit (IBC, 2014a) and the Construction Phase Toolkit (IBC, 2014b) can be downloaded from it without charge. Details of the documents' contents are as follows (Moore, 2013, p. 20):

- Design Development Phase Toolkit:
  - Design-Bid-Build
  - Educational Facility
    - Illustrative Protocol Guide
    - Illustrative BIM Protocol
    - Illustrative Protocol Template
    - Executive Summary
    - Overview Guide

- Construction Phase Toolkit:
  - Construction Management
  - Retail Facility
    - Illustrative Protocol Guide
    - Illustrative BIM Protocol
    - Illustrative Protocol Template
    - Executive Summary
    - Overview Guide
The following manuals are also relevant: Contract Language, BIM Execution Plan Toolkits, and FM Handover and Operations Toolkit (E. Lee, 2014).

The IBC is planning to publish 3 manuals on BIM practice (CSC, 2015):

- Volume 1: What is BIM?
- Volume 2: BIM: Company Context
- Volume 3: BIM: Project Context

CanBIM (Canada BIM Council) was founded in 2011 and it likewise supports the introduction of BIM in Canada. CanBIM represents the architecture, engineering, construction, owner and operator industry (AECOO) as well as Canada's educational institutions (CanBIM, 2011). CanBIM believes that the Canadian BIM community should build on existing bodies of rules, and it collaborates with the AEC community in Great Britain (Poirier, 2014). In 2012 the AEC (CAN) BIM Protocol was published as a platform-independent protocol relating to the use of BIM (McCallum, 2012).

2.4.2.2 Peripheral developments

In 2011 buildingSMART Canada (bSC) was formed, and it is operated by the members of the IBC (Moore, 2013). In 2013 the IBC and bSC in collaboration with Construction Specification Canada (CSC) and NBS UK conducted a survey in relation to BIM in Canada (IBC, 2015c). The survey was developed in Great Britain and adapted for the Canadian market. The aim was to find out how many Canadian companies view BIM as a process (Gilbert, 2015). This survey builds on, but is more detailed than, the 2011 survey conducted by the Canadian Construction Association (CCA) (Watson, 2013) the aim of which was to analyse the implementation of BIM in the Canadian market (CCA, 2011).

The Roadmap to Lifecycle Building Information Modeling in the Canadian AECOO Community which was published in 2014 contains plans for the publication of the practice manuals and the development of a national BIM standard, the Canadian Practice Manual for BIM (buildingSMART Canada, 2014).
2.4.3 BIM in the United States

2.4.3.1 Status quo in public construction sector

In the United States, the General Service Administration (GSA) is responsible for the construction and operation of all public buildings. GSA has been synonymous with BIM since the 3D-4D BIM program was established under the patronage of the Public Building Service (PBS) in 2003 (Khemlani, 2012). At the same time, 9 BIM pilot projects were launched in order to trial the implementation of BIM (Owen and Prins, 2010, p. 291). The national 3D-4D BIM program promotes value-creating digital visualisations, the use of simulation and optimisation tools, and the development of quality and efficiency over the entire life cycle (GSA Bim Guide Overview, 2007). Furthermore, since 2007 there has been a mandatory body of rules, the BIM Guide For Spatial Program Validation. This defines the minimum BIM requirements relating to architectural models for major projects carried out by the PBS. The following points are specified in the BIM Guide For Spatial Program Validation (PBS, 2007):

- General aims, history and processes for the submission of a building information model
- Use of zone stamps and zone boundaries
- Permitted objects and components within the zone
- Pre-analysis of the building information model for submission to the GSA

In addition to the GSA and PBS which concern themselves with the aforementioned objectives, there is a non-governmental and not-for-profit organisation called the National Institute of Building Sciences (NBIS). The NBIS's organisational structure is shown in the following graphic (Smith, 2013).
NBIS makes a comprehensive collection of documents relating to BIM available on its website http://www.wbdg.org (WBDG, 2013). Further documents about BIM which are published by the NBIS has traded under the name National BIM Standard-United States (NBIMS). NBIMS is a registered trademark. In 2007 the first National BIM Standard was published. This defines minimum requirements relating to BIM. Version 2 came out in 2012, and version 3 in 2015 (NBIMS, 2015, 2012a, 2007). GSA had its requirements incorporated into the standard that was published in 2007 (Owen and Prins, 2010, p. 291). The NBIM standards encompass cooperation between all the parties involved in construction during the design, construction and operational phases of a building (NBIMS, 2013).

In order to secure the active involvement of all stakeholders and to continually develop its operations, NBIS cooperates with the following partners and / or specifies the following main topics which require further investigation (NBIMS, 2007, p. 22):

- GSA (contents as above).
• Construction Operations Building Information Exchange (COBie). Supported by NASA. To improve use of facility management through more effective exchanging of information between contractors and principals.

• buildingSMART International: A development team which is tasked with specifying the information required for the use of IFC.

• Energy consumption: defining the exchanging of building information for calculating energy consumption together with the Lawrence Berkley Labs, U.S. department of Energy, and various software producers.

• Structural steelwork: Harmonising CIMsteel Integration Standards with IFC in collaboration with the Georgia Institute of Technology, National Institute of Standards and Technology, and various software producers.

• LEED: ecological auditing of buildings in collaboration with the U.S. Green Building Council.

• IFD library group: development of multilingual dictionaries and ontologies.

• Construction Specifications Institute (CSI): institute for construction specifications. Draws up and amends the standardisations and specifications used in the construction industry, and assists with the production of the necessary wordings relating to BIM (e.g. specifications of the information contained in a model).

• Charles Pankow Foundation: finances the development of the BIM standard in the field of reinforced concrete and precast concrete components.

• WALLie (Wall Standards Exchanges): specifying of an international wall layers agreement. Development of a model layer specification containing a definition of wall types in BIM over a building's lifetime.

• Exchanging of manufacturer-specific product information.

• Automatic costs estimating.

• US Coast Guard and International Building Code.

• BIM/GIS integration.

• Reviewing of information for estimating life cycle costs.
2.4.3.2 Peripheral developments

In 2006 the USACE, a corps of the US Army which provides civil engineering services, published a 'Building Information Modeling Roadmap'. The aim was to achieve a coordinated move towards BIM while taking account of the technological and business process risks. This roadmap was used at the time for a major project that USACE was about to undertake. (Brucker et al., 2006).

The following graphic shows the aims of the roadmap.

![USACE roadmap](image)

*Fig. 17. USACE roadmap (Brucker et al., 2006)*

The COBie (Construction Operations Building Information Exchange) information exchange format was developed in connection with this in 2007. This exchange format collates digital information that is necessary for the operation of a building (Chahrour, 2013, p. 48), and it conforms to the classes of the IFC model (Whyte, 2012, p. 3).

In 2012 UASCE published another roadmap which dealt with life cycle investigations in the BIM field and ensured the error-free adaptation of the goals of the first roadmap (UASCE, 2012). The US Coast Guard used BIM to build a large number of Sector Command Centers (SCCs) at various locations (AIA, 2014).
The Computer Integrated Construction (CIC) Research Program domiciled at Pennsylvania State University published the Project Execution Planning Guide. Its role is to:

- Clarify the workflow in a BIM project.
- Set out a structured procedure for creating and implementing a project using BIM.
- Ensure effective communication between the parties involved in a project in its early stages.

The second version of the document was published in 2001, and it is supported by the buildingSMART alliance among other bodies (Messner, 2011). There are further BIM guidelines and mandatory specifications and standards in the various states of the USA and at various universities (buildingSMART, 2015).
2.5 Northern Europe

2.5.1 BIM in Denmark

2.5.1.1 Status quo in public construction sector

The responsible authorities for the use of BIM in public construction sector are the Danish Palace & Property Agency (Bygningsstyrelsen), the Danish Defence and Construction Service, and the Danish University Property Agency (bygst, 2013; Smith, 2014a, p. 485).

In order to promote digital integration within public construction sector, the Danish government set up the Digital Construction Initiative (Det Digitale Byggeri). This was in place from 2003 to 2007 (Feldt, 2013). Its aim was to improve quality in the public construction sector, and to simultaneously reduce prices. It forms part of the overall "Growth on purpose" (Vækst med vilje) package (Aouad et al., 2007, p. 267). The initiative is based on 3 points of strategy (e-business W@tch, 2005, p. 2):

- Analysis relating to the framework conditions for digital design.
- Customers' requirements: (subdivided into 4 categories)
  - Electronic tendering with standard specifications and automatic quantity take-off.
  - 3D visualisation / simulation.
  - Information repository of the building.
  - Digital information for facility management.
- Development of proven procedures relating to ICT investments in the construction sector (best practice).

In 2007 the initiative led to new regulations for undertaking government construction projects (Anker Jensen and Ingi Jóhannesson, 2013, p. 102). The regulations are derived from the ICT Declaration and are to be applied to all central government projects with a value of over € 677,000. The regulations cover the following points (Steffensen, 2012):
• Use of the Danish buildings classification system based on ISO 12006-2.
• Project communication systems for exchanging digital information relating to an overall construction project.
• Use of 3D models (BIM) in competitive tenders, planning and design.
• Digital tendering, awarding and accounting based on 3D models.
• Handover of the collated information at the end of the construction process
• As a minimum requirement, the exchanging of information should be carried out via the IFC format.

The results of the Digital Construction Initiative were implemented in practice from 2008 - 2010 (Schwartz, 2014). In June 2011 the Danish parliament decided to expand the use of open BIM via IFC, and to introduce it on a mandatory basis for all public sector, local and regional construction projects (e.g. schools, libraries and sports facilities) with a value of over €2.7 M (buildingSMART, 2011). The Digital Construction Initiative enabled guidelines to be devised for working with 3D CAD systems (Owen and Prins, 2010, p. 290).

2.5.1.2 Peripheral developments
From 2010 to 2014 a research project called Cuneco Initiative (cuneco classification system) was carried out. This concerned the development, testing and implementation of common standards for the improved exchanging of information within the processes, from design to the construction, operation and maintenance of a building (cuneco, 2013).

bips (byggeri informationsteknologi produktivitet samarbejde) has published several guidelines for facilitating the development of the BIM methodology (Steffensen, 2012):
• The Danish building classification system (8 definitions and 29 classification tables).
• 3D working methods, guidelines. (How does one work using 3D models?)
bips is a not-for-profit organisation made up of construction industry companies. buildingSMART Norge is also a member.

Fig. 18. bips publications
(Steffensen, 2012)

### 2.5.2 BIM in Finland

#### 2.5.2.1 Status quo in public construction sector

The state-owned company Senate Properties has been carrying out projects using BIM since 2001, and in 2006 it announced that as from 2007 BIM would be mandatory for all projects over € 1.0 M in value (Karjalainen, 2013, p. 5, 2008, p. 5). Accordingly, Senate Properties published BIM guidelines in 2007 which contained specific model requirements (Kocatürk and Medjdoub, 2011, p. 128).

The National Common BIM Requirements (COBIM) which were published in 2012 are based on Senate Properties' 2007 guidelines (Henttinen, 2012). The 13 volumes describe the use of BIM in all phases of a construction project. COBIM is available in both English and Finnish. The titles of the several volumes are as follows (COBIM, 2012):
In addition, there is a further volume which outlines the 'Use of models in building supervision'. On 1st October 2007 it was decided on a mandatory basis that for all Senate Properties projects digital 3D models would have to be submitted according to the current IFC standard. This applied both to new-build and renovation / refurbishment projects. In connection with this, it was also stipulated that the BIM programs used must be certified according to IFC 2x3 (Wong et al., 2009b).

2.5.2.2 Peripheral developments

As part of the carried out projects by Senate Properties between 2001 and 2006, a study was investigating the construction of Auditorium Hall 600 (HUT-600) at Helsinki University of Technology. This study specifically involved analysing BIM in conjunction with the exchange format IFC (Kam and Fischer, 2002).

In the private sector, the Skanska Oy company is doing work in the BIM field, including research and development. In the university sector, the University of Technology and Tampere University have taken up the subject of BIM (Wong et al., 2010).
2.5.3 BIM in Sweden

2.5.3.1 Status quo in public construction sector

In 2009 the BIM Alliance Sweden was founded. It is a not-for-profit organisation. Since then, it has been working on the establishing of the BIM standard in Sweden (Poon, 2013). The 'BIM - Standardiseringsbehov' was published as a final standardisation report in 2013. The report was drawn up by the BIM Alliance Sweden in collaboration with the various industry partners and the Swedish Construction Federation. The aim of the report is to generate widespread support for the introduction of BIM (Eckholm et al., 2015, p. 2). The summary of the requirements relating to projects and resources included the following developments (Eckholm et al., 2015, p. 56):

- National BIM guidelines.
- Development of a BIM ranking system.
- Coordination of the information structures for BIM and GIS.
- Application interfaces for sharing common sources of information
- Development and amalgamation of IFC and LandXML.
- Development and use of open BIM as a collaborative format.

Bygghandlingar 90 Byggsektorns Rekommendationer för Redovisning av Byggprojekt – Digital Leveranser för Bygg och Förvaltning (Construction Document 90 Digital Supplies for Construction and Management) is an administrative guideline (Hopper, 2011) published by the Swedish Standards Institute (SIS). This guideline is continually updated (SIS, 2015a). It is Sweden's most important BIM guideline since it contains information about the submission of digital documents within construction projects (Mondrup et al., 2012, p. 5). In addition, several ISO standards for CAD files have been provided by SIS (SIS, 2015b). These include the CAD layer standard which specifies the names of the layers (ISO 13567). As the largest client for infrastructure measures, the Swedish government uses in particular the central Swedish Transport Administration 'Trafikverket' BIM system for major projects (BIM Alliance Sweden, 2014).
2.5.3.2 Peripheral developments

The central Transport Administration has specified in a strategy paper for the Stockholm Bypass project that the reviewing and approval of the project should be undertaken by the client using the 3D model (Jongeling, 2014, p. 19). As in Great Britain, public sector clients are taking a leading role in the ongoing development of BIM (Sanchez et al., 2014, p. 15).

2.5.4 BIM in Norway

2.5.4.1 Status quo in public construction sector

Statsbygg is the Norwegian Directorate of Public Construction and Property. It manages key parts of the Norwegian government's property portfolio. (Statsbygg, 2011). In 2007 5 BIM pilot projects were carried out (Danielsen, 2007). Since 2010 the use of open BIM with IFC has been mandatory for all Statsbygg projects (Wong et al., 2009b, p. 4). The bodies of rules that apply to working with BIM in Norway are: 1) the Statsbygg BIM Manual, and 2) PROSJEKTERINGSANVISNING PA 0603 DAK-TEGNINGER. While the aim of 1) is to describe the requirements for the adoption of BIM and the IFC format, 2) is a type of CAD manual which sets out the graphical requirements in respect of a BIM drawing (Statsbygg, 2013, p. 6). Work on drawing up a Statsbygg BIM manual began in 2008. Version 1.2.1 is the first to be made available to the interested construction companies (Mohus, 2012, p. 3). In March 2012 the Standards Norway committee decided to develop the standards SN/K 529 BIM Object Libraries and SN/K 534 Legal framework for New Ways of interoperability (Sunesen, 2012).

2.5.4.2 Peripheral developments

SINTEF (The Foundation for Scientific and Industrial Research) is the leading organisation involved with BIM research. The Norwegian International Alliance for Interoperability Forum actively defines the rules for the exchanging of information (Owen and Prins, 2010, p. 290).

The Norwegian Home Builders' Association, the trade association for builders of residential and holiday homes, likewise published a BIM manual in 2011 and
2012 (boligBIM, 2012, 2011). The aim of the manuals is to specify the areas in which time savings can be made through the use of the BIM process (buildingSmart, 2012). Due to its commitment to the open BIM standard, Statsbygg collaborates closely with buildingSMART Norway (Sunesen, 2011).
2.6 Central and Southern Europe

2.6.1 BIM in France

2.6.1.1 Status quo in public construction sector

In 2014 the French Ministry of Construction (Ministère du Logement, de l’Égalité des territoires et de la Ruralité) published a report on the topic of BIM in France. The report contains recommendations for mobilising and supporting the construction sector as well as strategic collaborative measures for jointly implementing the digital revolution (Knutt, 2015). The author of the report which is entitled "Mission Numérique Bâtiment" is Betrand Delcambre, who was chosen by the French Ministry of Construction as its BIM ambassador. Another aim is to identify strategic development opportunities in relation to the introduction of digital tools by all the parties involved in construction by 2017. This is supported by the Ministry of housing and the ministry of culture, the ministry of the economy, and the ministry of finance (Castaing and Mat, 2015). France is planning to introduce BIM on a mandatory basis for the public construction sector by 2017 (Geoff, 2014).

2.6.1.2 Peripheral developments

Over the next 3 years a total of € 20.0 M will be spent on promoting the development of BIM in France (buidlingSMART International, 2014).

2.6.2 BIM in Germany

2.6.2.1 Status quo in public construction sector

In 2013 the 'BIM guidelines for Germany - Information and Advice' were published by the Federal Institute for Research on Building, Urban Affairs and Spatial Development as part of the ZukunftBAU research project. The buildingSMART German Speaking Chapter is actively promoting awareness of BIM in Germany. The 'planen-bauen 4.0' (planning-building 4.0) company was founded in 2015. This acts as a centre of competence and discussion partner for BIM research, rule setting and market implementation (Die Deutsche Bauindustrie, 2015).
2.6.2.2 Peripheral developments

Regular meetings of representatives of various federations, professional associations, universities and ministries have taken place on the subject of BIM since 2010 (Schuff, 2014). In 2013 the 'Building Information Modelling Coordination Committee' (KK-BIM) was set up by the building and building management systems company of the Association of German Engineers (VDI). A key aspect of the Coordination Committee's work is the specifying of main focuses and recommendations as well as policy and decision-making (VDI, o. J.). The 'Building Information Modelling, VDI, guidelines for achieving targets' agenda were published in 2014. As the largest technical / scientific grouping, the VDI is undertaking the drawing up of rules relating to BIM (Lenhart, 2014, p. 2). Zonal and structural component characteristics can be added to a BIM system in accordance with specification DIN SPEC 91400 (buildingSMART, 2015a).

2.6.3 BIM in Italy

2.6.3.1 Status quo in public construction sector

A database has been developed as part of the national InnovANCE research project. (Guidice and Osello, 2013). The research project has been funded by the Italian Ministry for economic development, and it is intended to produce a building database containing information from the design to the construction as well as the entire life cycle (Pavan et al., 2014).

2.6.3.2 Peripheral developments

Italy has been carrying out some BIM projects since 2006 (Karam and Jungho, 2014). Equally, some work from the university sector has also been published (Johansson et al., 2014, p. 34).
2.6.4 BIM in the Netherlands

2.6.4.1 Status quo in public construction sector

The Government Real Estate Agency which works for the Dutch Ministry of the Interior and Kingdom Relations uses BIM in order to obtain reliable and durable information about the building stock that it manages (Rijksvastgoedbedrijf, 2014). The foundation was laid in 2011 with the decision to introduce BIM on a mandatory basis for all public projects with a value of over € 10.0 M (buildingSMART, 2011). The Dutch BIM standard, which is only available in Dutch, was published in 2011 (K. Stuhlmacher, 2014). The Netherlands government is planning to make improvements over the long term to the DBFMO (Design, Build, Finance, Maintain, Operate) digital planning, building and operating process in the context of PPP (public private partnership) contracts (Straub et al., 2012). In 2012 the Dutch Ministry of the Interior and Kingdom Relations made the use of open BIM with IFC mandatory for maintenance contracts for large scale constructions (Baxter, 2013; Zeiss, 2013). This was accompanied by the drawing up of an English version of the Dutch BIM standard. This defines the specifications for BIM content and the IFC model and objects, as well as for CAD drawings. In addition, it describes the additional documents which have to be enclosed with a building information model submission. In February 2013, version 1.1 of the Dutch BIM standard was published in Dutch. The main changes compared to version 1.0.1 are (Gertjan, 2013):

- **the concept of LOD is deleted**;
- **the use of layers in IFC has been replaced by the use of a classification**;
- **all storey transcendent spaces per floor should be split**;
- **naming of file names is simplified**.

2.6.4.2 Peripheral developments

Furthermore, monetary investments by public sector clients (e.g. Rijkswaterstaat) are promoting the development of further standards in order to
facilitate working with open BIM and IFC. These standards are shown in the following table (BOUW INFORMATIE RAAD, 2014).

<table>
<thead>
<tr>
<th>Standard (Managed by)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CB-NL (BIR)</td>
<td>The CB-NL is a digital description of generic, reusable concepts (types or sorts) related to physically built objects and usable spaces and areas. It can be used by the B&amp;U, GWW and the Spatial Environment throughout the entire lifecycle. In other words the CB-NL is a dictionary for the entire building industry. (source: <a href="http://www.cb-nl.nl">www.cb-nl.nl</a>) Internationally the CB-NL complies with the standard IFD, the International Framework Dictionary.</td>
</tr>
<tr>
<td>COINS (BR)</td>
<td>COINS (Constructive Objects and the Integration of Process and Systems) underpins the exchange of Systems Engineering Information and therefore ensures that an object tree, GIS, 2D drawings, 3D models, IFC models and object type libraries successfully cohere with each other within one database. (source: <a href="http://www.coinsweb.nl">www.coinsweb.nl</a>)</td>
</tr>
<tr>
<td>CityGML (OGC/Geonovum)</td>
<td>CityGML is a data model for the representation of urban objects in 3D. It defines the classes and relationships between the most relevant topographical objects in cities and regional models in relation to their outward appearance as well as their geometric, topological and semantic characteristics. (based in part on: <a href="http://nl.wikipedia.org/wiki/Citygml">http://nl.wikipedia.org/wiki/Citygml</a>)</td>
</tr>
<tr>
<td>ETIM (ETIM)</td>
<td>The European Technical Information Model for technical products, set up by the HVAC sector (heating, ventilation, and air conditioning). It is a system of classification for a logical, unambiguous division of products in different article classes and the determination of the selective product characteristics in the class. (source <a href="http://www.etim.nl">www.etim.nl</a>)</td>
</tr>
<tr>
<td>GB-CAS (STABU)</td>
<td>The Integrated Building CAD-Agreement System (GB CAS) is primarily aimed at structured drawings in a 2D environment and information exchange for the AEC sector. (source: <a href="http://www.gbcas.nl">www.gbcas.nl</a>)</td>
</tr>
<tr>
<td>GML (OGC/Geonovum)</td>
<td>GML, also known as ISO19136, is an Extensible Markup Language (XML) for the representation, transferral and storage of geographic (spatial and positioned) information which was formulated by the OGC. This includes both the geometry and the properties of geographical characteristics. (based in part on: <a href="http://nl.wikipedia.org/wiki/Geography_Markup_Language">http://nl.wikipedia.org/wiki/Geography_Markup_Language</a>)</td>
</tr>
</tbody>
</table>
### Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

#### 2 Analysis of the international application of the BIM methodology in public sector

<table>
<thead>
<tr>
<th>Methodology</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IFC (building SMART)</td>
<td>The Industry Foundation Classes (IFC) form an open, internationally standardised data model for the exchange and sharing of specific BIM Information between different software applications and parties in the building process. The standard is available for the houses and offices sector and is currently being expanded by buildingSMART to include infrastructure.</td>
</tr>
<tr>
<td>IMGeo (Geonovum)</td>
<td>IMGeo (Information Model Geography) forms the basis for the exchange of 3D geo-information and contains agreements about the exchange of plus and maintenance topography. This includes agreements relating to the legally compulsory BGT (Basis Registration Large-Scale Topography) (based in part on source: <a href="http://www.geonovum.nl">www.geonovum.nl</a>)</td>
</tr>
<tr>
<td>Nat.BIM-Protocol Checklist (BIR)</td>
<td>One national BIM protocol checklist to ensure that the operational and legal agreements for BIM projects are accurately and adequately made and anchored. The development of such a protocol checklist will be looked into during the BIR’s BIM program.</td>
</tr>
<tr>
<td>NLCS (BIR/SBRCURnet)</td>
<td>NLCS is the 2D standard for CAD in the Dutch GWW sector. The NLCS encompasses agreements about metadata, digital signatures, the outward appearance of the drawing and – in particular – the file composition of the 2D drawing. (source: <a href="http://www.ncls-gww.nl">www.ncls-gww.nl</a>)</td>
</tr>
<tr>
<td>NL-SfB (BNA/STABU)</td>
<td>The NL-SfB is a classification based on functions which the different parts of the building have to fulfil. The NL/SfB is based on CI/SfB, the international Construction Index. (source: <a href="http://www.stabu.org">www.stabu.org</a>)</td>
</tr>
<tr>
<td>S@les in de Bouw</td>
<td>Independent communication standard (XML-standard) for electronic information exchange between parties active in the building and HVAC (heating, ventilation, air conditioning) sector, notably for communication concerning purchase and sale transactions.</td>
</tr>
<tr>
<td>SUF (CROW, STABU)</td>
<td>Standard Exchange Format used for the overall inspection of public space, among other things. It can be used by for the efficient exchange of information by administrators and inspectors. It can also be used in relation to roads, trees and sewerage (for example CROW’s ‘SUF-Roads’). Moreover, SUF can also be used within STABU for the exchange of electronically-determined subdivisions of the specification document between participating parties. (source: based in part on <a href="http://www.crow.nl">www.crow.nl</a> and <a href="http://www.stabu.org">www.stabu.org</a>)</td>
</tr>
<tr>
<td>VISI (BIR/CROW)</td>
<td>VISI forms the basis for communication and information transfer within organizations and building and other projects. It makes sure that project responsibilities are well shared. This well accepted open standard structures, safeguards and stores communication agreements sector-wide. (source: <a href="http://www.crow.nl/visi">www.crow.nl/visi</a>). VISI is now used internationally due to its inclusion of ISO 29481-2:2012 as part 2 – ‘Interaction Framework’, of the ISO ISO/TS 12911:2012 standard ‘Building information Models – Information Delivery Manual’</td>
</tr>
</tbody>
</table>
Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

2 Analysis of the international application of the BIM methodology in public sector

A Web Feature Service (WFS) is an interface for the digital retrieval, delivery and editing of geographical vector data and accompanying administrative data from data banks. It uses GML for data transferral and leads to detailed access on the level of ‘features’ and their properties. It does more, therefore, than provide access on a file level. (based in part on: http://nl.wikipedia.org/wiki/Web_Feature_Service)

A Web Map Service (WMS) publicises ‘maps’ (this means a visual proposal of the geospatial data, not the data itself) on the world wide web. A WMS provides a way to simultaneously gain a visual overview of complex and distributed geographical maps over the internet. This mostly comes in the form of a JPEG or PNG. (source: http://nl.wikipedia.org/wiki/WMS)

Table 5. Further standards in the Netherlands

Apart from VISI, the standards listed in Table 5 are not mandatory. Rather, it is the case that public sector clients recommend their use.

Particular importance should be ascribed to CB-NL (conceptenbibliotheek Nederland). It is about the development of a Dutch concept library for major construction companies operating in the public sector.
This is intended to establish a common language within the construction industry in the Netherlands (CB-NL, 2015). Development began in 2014 and has received funding of €2.0 M. Once it is completed, the intention is to incorporate it into the buildingSMART Data Dictionary Browser (bSSD) (buildingSMART, 2015b).

2.6.5 BIM in Spain

2.6.5.1 Status quo in public construction sector

The buildingSMART Spanish chapter which was founded in 2014 makes the uBIM guidelines available on its website. According to the buildingSMART Spanish chapter this is an adaptation of the Finnish Common BIM Requirements 2012 (COBIM) which have been adapted to the current Spanish standards and rules (buildingSmart Spanish Chapter, 2014). As can be seen in the next graphic, the guidelines are divided into several documents, as they are in Finland (cf. 3.5.2). The documents can be downloaded in Spanish.

![Fig. 20. uBIM buildingSMART Spanish Chapter](builddingSmart Spanish Chapter, 2014)
2.6.5.2 Peripheral developments

The exchanging of information in the construction sector is monitored by FIDE (Formato de Intercambio de Datos en la Edificación). This is a committee comprising representatives of various ministries, regional governments and universities in Spain. The committee has the task of providing an information exchange standard for the various stakeholders in the construction sector. FIDE is a public standard, and it is compatible with other international standards such as IFC (FIDE, 2015).
2.7 Oceania

2.7.1 BIM in Australia

2.7.1.1 Status quo in public construction sector

In 2009 the Cooperative Research Centre (CRC) for Construction Innovation, an Australian government programme, published the National BIM Guidelines (Cooperative Research Centre for Construction Innovation (Australia), 2009). In 2011 the National BIM Guide was published by NATSPEC BIM (NATSPEC, 2011). Further bodies of rules followed, including the Australian and New Zealand Revit Standards (ANZRS, 2014) and the AUS Autodesk Revit MEP templates (BIM-MEP AUS, 2015). The Australian government has not declared the use of BIM to be mandatory (Smith, 2014b, p. 477).

A research team set up by CRC for Construction Innovation has developed an automated system for reviewing IFC models. The system DesignCheck, reviews requirements relating to design and building regulations, but also those relating to building codes (Ding et al., 2006, p. 1).

2.7.1.2 Peripheral developments

buildingSMART is committed to establishing open BIM. In 2012 buildingSMART Australasia published the National BIM Initiative. The initiative recommends that the construction industry and the Australian government should work together to bring about the fast implementation of BIM (buildingSMART, 2012).

The six main objectives of the initiative are (Mitchell et al., 2012, p. 4):

- New types of contract for improved collaborative working.
- Clear standards for BIM users.
- A new multi-disciplinary approach to the training of specialist construction personnel.
- Digitalisation of construction objects for intelligent building models.
- Acceptance of standards for the cooperative digital exchange of information.
Guidelines for evaluating and approving BIM-based projects.

Pilot projects for trialling the use of BIM.

3D BIM collaboration between all the Australian government bodies by 1st July 2016.

In 2014 the Australian Productivity Commission recommended that BIM should be used in all complex government projects (Kannegieter, 2014). The Australian Department of Defence wants to take over management of BIM implementation for public institutions (Howe, 2013).

### 2.7.2 BIM in New Zealand

#### 2.7.2.1 Status quo in public construction sector

In 2014 the Building and Construction Productivity Partnership, an organisation comprising industry and government bodies, published the New Zealand BIM Handbook (MBIE, 2014). The purpose of the handbook is (BIM Acceleration Committee, 2014, p. 6):

- to promote the use of BIM throughout the project life cycle,
- to create a common language in the industry,
- to clarify the duties of architects and specialist planners,
- to improve coordination during planning and in the construction phase,
- to promote a holistic project approach to facility management,
- and to set clear paths for future developments to follow.

The BIM Acceleration Committee, which is part of the Building and Construction Productivity Partnership, has the task of increasing the use of BIM in New Zealand (BIM ACCELERATION COMMITTEE, 2014a). The New Zealand government's actions in this field are generally modelled on those of its counterparts in Great Britain, Australia and Singapore (BIM Acceleration Committee, 2014, p. 8).
2.7.2.2 Peripheral developments

In the study report: Building Industry Performance Measures which was published in 2012 BIM is named as one of the potential projects for achieving a 20% increase in productivity in the construction sector by 2020 (Page and Curtis, 2012, p. 5).

A study of the development of BIM in New Zealand was published in 2013 by Masterspec, New Zealand’s market leader in the field of specification systems and software for the construction industry. The study entitled 'New Zealand National BIM Survey Report 2013' was produced for the construction industry and was funded by NBS UK and the Building and Construction Productivity Partnership. It reports, among other things, on potential obstacles to the introduction of BIM and the lack of sector-wide protocols (Masterspec, 2013).
3. Summary of the analysis

The investigations show that the application of the BIM methodology in public construction sector varies greatly between the countries that have been discussed here. This is due to the differing levels of progress made in implementing guidelines, specifications or standards in public construction sector.

3.1 Stage of development in the countries analysed

Initial developments can be noted in Brazil. Here official bodies in the architecture and urban planning fields are closely linked with each other, and draft bodies of rules for BIM. In China the development of the BIM methodology has been incorporated into the 11th and 12th National Five-Year Plans. IFC 2x has been declared to be the national standard. Sweden uses 3D models for major projects in the field of infrastructure planning. As in Great Britain, public sector clients are taking a leading role in the ongoing development of BIM. Various ISO standards relating to BIM exist in this countries, but their use in public construction sector is not mandatory.

In Germany, the government has pursued the development of the BIM methodology and has put together committees representing industry, universities and software vendors. These committees have the job of promoting and assisting the introduction of BIM. The initial national steps can be seen in France in the form of a report on the potential introduction of the BIM methodology and the beginning of the digital revolution. Although rudimentary guidelines exist, the use of the BIM methodology within public construction sector is not mandatory or recommended in either country. In Spain, the Finnish National Common BIM Requirements have been adapted and adjusted to the current Spanish standards, language and rules / regulations. Use of this standard is not mandatory. In Italy some construction projects have been carried out using BIM since 2006. Furthermore, there are national research
projects which deal with sub-areas of BIM methodology. There is no consistent national solution in the form of committees or similar institutions.

Since 2006 Hong Kong has gained experience of the BIM methodology extending from feasibility studies to the construction phase. Several authorities are responsible for its introduction here. Similarly in Japan, the first public sector construction projects have been implemented using BIM methods. Canada is working with Great Britain on the development of the BIM methodology, and it is already making some guidelines available. In Australia and New Zealand there are guidelines relating to BIM practice and working methods. In the countries that have been mentioned in this paragraph the use of the guidelines is merely recommended.

In Singapore, South Korea, the United States, Denmark, Finland, Norway and the Netherlands, use of the BIM methodology is mandatory in the public sector construction field. The use of standards and definitions is laid down and described in official guidelines produced by state bodies. Using and complying with the rules set out in these guidelines is mandatory when working with public sector clients or when working on government construction projects.

### 3.2 Mandatory use of the BIM methodology

The following table provides an overview of the countries where the application of the BIM methodology is mandatory. Furthermore, it lists the boundary conditions in each country which specify when the BIM methodology is used.

<table>
<thead>
<tr>
<th>Country</th>
<th>Governmental / public institution or state involved institution. Supports BIM * or is using BIM in the public sector</th>
<th>Guidelines or regulations applied in the public construction sector?</th>
<th>Used in public construction projects from / above</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>China</td>
<td>China BIM Union*</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Hong Kong</td>
<td>The Hong Kong Housing Authority</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Table 6. Worldwide application of the BIM methodology in the public sector

<table>
<thead>
<tr>
<th>Country</th>
<th>Institution</th>
<th>BIM Integration</th>
<th>Information Access</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>Ministry of Land, Infrastructure and Transport</td>
<td>X</td>
<td>X</td>
<td>No information</td>
</tr>
<tr>
<td>Singapore</td>
<td>Building Construction Authority</td>
<td>X</td>
<td>X</td>
<td>5000 sqm</td>
</tr>
<tr>
<td>South Korea</td>
<td>Public Procurement Service</td>
<td>X</td>
<td>X</td>
<td>€ 27.6 M (as from 2016 for all projects)</td>
</tr>
<tr>
<td>Great Britain</td>
<td>Cabinet Office Her Majesty’s Government</td>
<td>X</td>
<td>X</td>
<td>From 2016</td>
</tr>
<tr>
<td>Brazil</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canada</td>
<td>Institute for BIM in Canada</td>
<td>X</td>
<td>X</td>
<td>No information</td>
</tr>
<tr>
<td>United States of America</td>
<td>General Service Administration Public Building Service</td>
<td>X</td>
<td>X</td>
<td>No information</td>
</tr>
<tr>
<td>Denmark</td>
<td>Danish Building &amp; Property Agency</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Finland</td>
<td>Senate Properties</td>
<td>X</td>
<td>X</td>
<td>No limitation</td>
</tr>
<tr>
<td>Sweden</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Norway</td>
<td>Statsbygg</td>
<td>X</td>
<td>X</td>
<td>No limitation</td>
</tr>
<tr>
<td>France</td>
<td>French Ministry of Construction*</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>Federal Institute for Research on Building, Urban Affairs and Spatial Development*</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>Ministry of Economic Development*</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Netherlands</td>
<td>Government Real Estate Agency</td>
<td>X</td>
<td>X</td>
<td>€ 10.0 M</td>
</tr>
<tr>
<td>Spain</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>Cooperative Research Centre (CRC) for Construction Innovation</td>
<td>X</td>
<td>X</td>
<td>No information</td>
</tr>
<tr>
<td>New Zealand</td>
<td>Building and Construction Productivity Partnership</td>
<td>X</td>
<td>X</td>
<td>No information</td>
</tr>
</tbody>
</table>
3.3 Cooperative arrangements

Furthermore, it should be noted that development of some aspects is being pursued through cooperation between different countries. The Statsbygg manual is based on the Norwegian standard (NS8353 CAD manual), and it is being drawn up in coordination with the NBIMS Standard in the USA (Wong et al., 2009b, p. 4). In Australia and New Zealand there are the Australian and New Zealand Revit Standards. New Zealand is following the example of Great Britain, Australia and Singapore. Canada is working with Great Britain on the development of the BIM methodology. Great Britain is entering into a bilateral agreement with buildingSMART US for the development of a national BIM standard based on the principles of interoperability. COBie is used in Great Britain and the United States.

3.4 Reason for mandatory use

When considering the countries where use of BIM is mandatory in public construction sector, it becomes clear that they have one thing in common, namely state-owned construction companies whose main activity is the construction, operation and management of a enormous building stock. Their activities relate to conversion and construction work as well as the renovation and refurbishment of public and government-owned buildings. Here too, there are standards and / or specifications which not only stipulate the use of BIM but also actively support it. The decision to make the use of BIM mandatory is predominantly explained in terms of increased efficiency and simultaneous cost savings achieved through automated processes in the specialist disciplines (buildingSMART, 2010; Cabinet Office, 2011; Poon, 2013; Zghari, 2013).

3.5 Use of non-proprietary interfaces

In Northern Europe and Scandinavia buildingSMART is heavily involved in the development of the BIM methodology. Open BIM in conjunction with IFC is used in public construction sector in all the countries (Wong et al., 2010). The development of the IFC technology is based on buildingSMART. Only in the United States of America and Great Britain is COBie currently used as an
additional specification for data exchange. This is not however a fully adequate information exchange interface. COBie should rather be regarded as a descriptive specification of subsets (e.g. facility management) within an IFC file. Furthermore, the use of COBie is associated with problems, such as the manual evaluation of Excel tables (Malleson et al., 2013, p. 9). IFC is therefore regarded as the only universally valid, interoperable information exchange format within public construction sector, and it is examined further in Chapter 4.

The following table shows the countries in which buildingSMART operates. As buildingSMART is the developer of IFC, those countries which are shown as using it can be assumed to use IFC.

<table>
<thead>
<tr>
<th>Country</th>
<th>buildingSMART available</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>Yes. IFC has been proclaimed as a national standard</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>Yes</td>
</tr>
<tr>
<td>Japan</td>
<td>Yes</td>
</tr>
<tr>
<td>Singapore</td>
<td>Yes. In addition see Table 8</td>
</tr>
<tr>
<td>South Korea</td>
<td>No</td>
</tr>
<tr>
<td>Great Britain</td>
<td>Yes</td>
</tr>
<tr>
<td>Brazil</td>
<td>No</td>
</tr>
<tr>
<td>Canada</td>
<td>Yes</td>
</tr>
<tr>
<td>United States of America</td>
<td>Yes</td>
</tr>
<tr>
<td>Denmark</td>
<td>Yes</td>
</tr>
<tr>
<td>Finland</td>
<td>Yes</td>
</tr>
<tr>
<td>Sweden</td>
<td>Yes</td>
</tr>
</tbody>
</table>
3.6 Validation systems in public construction sector

In the following countries there are web-based reviewing and validation systems for the submission of building information models. Reviewing and validation is carried out using an IFC model. The systems are listed in the following table.

<table>
<thead>
<tr>
<th>Country</th>
<th>Name of the system</th>
<th>Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singapore</td>
<td>CORENET</td>
<td>Web-based e-Submission checking system for digital construction plans in IFC format</td>
</tr>
<tr>
<td>South Korea</td>
<td>SEUMTER</td>
<td>Review system of 3D building models against the valid Korean public construction laws</td>
</tr>
<tr>
<td>Great Britain</td>
<td>BIM Toolkit</td>
<td>Web-based digital building library as well as an assessment centre of the BIM level</td>
</tr>
<tr>
<td>Australia</td>
<td>DesignCheck</td>
<td>Checking various requirements of the design stage, building codes and further details during the construction process</td>
</tr>
</tbody>
</table>

Table 8. web-based reviewing and validation system
3.7 Sustainability within existing specifications

In addition, it was investigated whether sustainability is mentioned in the various countries with the key words "Green" or "Sustainable" in the respective bodies of rules or other relevant documents. The following table shows the results of this investigation. The countries are listed in the same order as in Table 6. The countries where there are no guidelines are not shown.

<table>
<thead>
<tr>
<th>Country</th>
<th>Name of the document analysed</th>
<th>Keyword available</th>
<th>Keywords used in the sense of sustainable construction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>BIM Project Specification 2011</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>Available only in Japanese</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Singapore</td>
<td>Singapore BIM Guide 2013</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>South Korea</td>
<td>Available only in Korean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Great Britain</td>
<td>AEC (UK) BIM Protocol 2012</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Digital Built Britain 2015</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Government Construction Strategy 2011</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
### Table 9. Mentioning of sustainability in the guidelines

<table>
<thead>
<tr>
<th>Country</th>
<th>Document</th>
<th>X</th>
<th>X</th>
<th>X</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>AEC (CAN) BIM Protocol 2012</td>
<td></td>
<td></td>
<td>X</td>
<td>Use of BIM to achieve sustainability in the construction industry.</td>
</tr>
<tr>
<td>United States of America</td>
<td>GSA BIM Guide Overview 2007</td>
<td>X</td>
<td></td>
<td></td>
<td>Achieve sustainability in the construction industry.</td>
</tr>
<tr>
<td></td>
<td>GSA BIM Guide Energy Performance</td>
<td>X</td>
<td>X</td>
<td></td>
<td>Achieve sustainability in the construction industry.</td>
</tr>
<tr>
<td>Denmark</td>
<td>Not accessible</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finland</td>
<td>COBIM Series 1 General part</td>
<td>X</td>
<td></td>
<td></td>
<td>Use of BIM to achieve sustainability in the construction industry.</td>
</tr>
<tr>
<td></td>
<td>Common BIM Requirements 2012 Energy analysis</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Norway</td>
<td>Statsbygg BIM Manual 1.2.1 2013</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Netherlands</td>
<td>Available only in Dutch</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>NATSPEC National BIM Guide 2011</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>National Guidelines for Digital Modelling 2009</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Zealand</td>
<td>New Zealand BIM Handbook 2014</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The analysis carried out in this chapter does not enable any statement to be made about existing sustainability certification systems within public...
construction sector. Only in the United States of America is reference made to existing systems. The existing sustainability certification systems are therefore examined in greater detail in Chapter 6.

### 3.8 Non-governmental institutions

Furthermore, there are various non-governmental organisations in the business, research and university sectors which also are involved in the introduction of the BIM methodology. They exist both, in countries where the use of BIM is already mandatory and those countries where there is not yet any such obligation. The following table lists these non-governmental organisations.

<table>
<thead>
<tr>
<th>Country</th>
<th>Other relevant non-governmental organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>No information</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>The Hong Kong Institute of Building Information Modelling Hong Kong Construction Industry Council</td>
</tr>
<tr>
<td>Japan</td>
<td>Japan Institute of Architects</td>
</tr>
<tr>
<td>Singapore</td>
<td>No information</td>
</tr>
<tr>
<td>South Korea</td>
<td>No information</td>
</tr>
<tr>
<td>Great Britain</td>
<td>National Building Specifications BIM Task Group</td>
</tr>
<tr>
<td>Brazil</td>
<td>Brazilian Association of Architecture Firms</td>
</tr>
<tr>
<td>Canada</td>
<td>Institute for BIM in Canada Canada BIM Council</td>
</tr>
<tr>
<td>United States of America</td>
<td>National Institute of Building Sciences National BIM Standard-United States</td>
</tr>
<tr>
<td>Denmark</td>
<td>bips (byggeri informationsteknologi produktivitet samarbejde)</td>
</tr>
</tbody>
</table>
3.9 BIM maturity models in public construction sector

Great Britain is aiming to achieve a higher level of BIM. The BIM level is determined using a BIM maturity model. This paper investigates what the task of this maturity model is, and in which countries models actually exist for determining the BIM maturity in public construction sector. The analysis of BIM maturity models begins in the next chapter.
4. Models for determining the BIM maturity

4.1 Definition of maturity models

The maturity models can be used to compare and quantify various management practices (Zeb et al., 2013). Maturity models describe the development of a functional unit over time. The functional unit may be a person, an organisation, a technology, a product, or a procedure etc. The models highlight ways to make improvements, but they can also be used as a basis for the comparison of functional units (Kimko, 2001). Benchmarking is possible for identifying and improving processes and procedures. There are a large number of maturity models in existence across various sectors of industry, but few for the construction industry (Zeb et al., 2013). The models have already been used for several decades in fields such as software development (Paulik, 2009) or the electronic processing of information (Gibson and Nolan, 1974). The concept of process maturity has originated from the 'Total Quality Management' movement. Techniques were required for visualising processes and improving the maturity of procedures (Cooke-Davies and Arzymanow, 2003). Maturity models have the following characteristics (Weerdmester et al., 2003):

- The level of development of a functional unit is simplified and described using a limited number of maturity levels (usually between four and six).
- The individual grades of the levels are described in terms of specific requirements which the functional unit should fulfil.
- The individual grades are sequentially arranged. There is an initial level and a final level. The highest level is perfection.
- The course of development takes the functional unit from the lowest to the highest level. No level can be skipped.

Maturity level are also used in construction – in the BIM field. Here the BIM maturity model relates to the quality, reproducibility and integratedness of the provision of a BIM-enabled service (Kassem et al., 2013, p. 1). This can be measured using various methods, and it should be regarded as a practical method for systematically evaluating the degree of implementation of the BIM
methodology at the company level (Mom and Hsieh Hsien, 2012). The various maturity models can be subdivided into two categories. A) The evaluation of the maturity level over the course of a construction project based on the use of innovative means, and B) the evaluation of the maturity of an organisation that uses or implements BIM (Giel and Raja, 2012).

In this chapter, BIM maturity models used in public and non-public sector are highlighted and discussed.

### 4.2 Public sector

#### 4.2.1 BIM proficiency matrix

At Indiana University (IU) use of the Building Information Modeling Guidelines and Standards for Architects, Engineers, and Contractors has been mandatory since 2009 for all construction and renovation projects costing over $5.0 M. In these guidelines the use of the BIM proficiency matrix (BPM) is described as a requirement (IU, 2012a). BPM was developed in order to measure a construction company's expertise in implementing the BIM processes within the company. This matrix enables IU to evaluate the company's abilities and knowledge in relation to working in a BIM environment. It is used by Indiana University as one criterion for pre-selecting construction companies (IU, 2014, 2009). The BPM comprises eight main categories relating to the contractual partner's abilities. Each category is broken down into four maturity fields. The construction company fills in the matrix manually (in the form of an Excel spreadsheet) based on its BIM experience. This is then analysed by an IU adviser. The points scored are added together from the eight categories and 4 maturity levels. The score provides information about the company's maturity level in relation to the use of BIM processes (Chae and Kang, 2015). The maximum possible score is 32 (Liu, 2010). Roughly 50 firms have been approved through this procedure at IU (IU, 2012b).
Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

4 Models for determining the BIM maturity

Fig. 21. BIM proficiency matrix
(Phillips, 2013)
4.2.2 BIM CMM and Interactive CMM

The Capability Maturity Model (CMM) was introduced in 2007 alongside version 1 of the National BIM Standard (NBIMS). It is used to measure the maturity of a BIM system, and it also supports the BIM minimum requirements criteria according to the NBIMS. This maturity model is not only able to ascertain whether the existing model includes the requirements of a building information model, it can also evaluate a fully integrated and open life cycle building information model. It is a Microsoft Excel file which contains the Tabular Maturity Model and the Interactive Maturity Model (NBIMS, 2012b). The contents of the worksheets (six in all) are analysed below.

Fig. 22. Microsoft Excel file worksheets
(NBIMS, 2012b)

The Tabular Maturity Model is a static Microsoft Excel spreadsheet containing the associated worksheets 'Category Descriptions' and 'Matrix Definitions'.

![Tabular Maturity Model](image)

<table>
<thead>
<tr>
<th>Tabular Maturity Model</th>
<th>Category Descriptions</th>
<th>Matrix Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Tabular Maturity Model" /></td>
<td><img src="image" alt="Category Descriptions" /></td>
<td><img src="image" alt="Matrix Definitions" /></td>
</tr>
</tbody>
</table>

Fig. 23. The Tabular CMM in the Tabular Maturity Model worksheet
(NBIMS, 2012b)
The column on the left-hand side lists maturity levels 1 to 10 (McCuen, 2008). Various descriptions are provided for the 10 maturity levels in the 11 categories (A-K). Each category description serves to explain the assessment of the maturity level. (Smith and Tardif, 2012). They enable the maturity level of a company or an individual project to be ascertained. The descriptions are subjective and open to interpretation (NBIMS, 2007).

This is followed by the Category Description worksheet. This explains the factual significance of the respective categories in more detail (NBIMS, 2012b).

<table>
<thead>
<tr>
<th>Category</th>
<th>Category Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Data Richness</td>
<td>Identifies the completeness of the Building Information Model from initially very few pieces of unrelated data to the point of it becoming valuable information and ultimately corporate knowledge about a facility</td>
</tr>
<tr>
<td>B Lifecycle Views</td>
<td>Views refer to the phases of the project and identifying how many phases are to be covered by the BIM. One would start as individual stove pipes of information and then begin linking those together and taking advantage of information gathered by the authoritative source of the information. This category has high cost reduction, high value implications based on the elimination of duplicative data gathering. The goal would be to support functions outside the traditional facility management roles, such as first responders.</td>
</tr>
<tr>
<td>C Roles or Disciplines</td>
<td>Roles refer to the players involved in the business process and how the information flows. This is also critical to reducing the cost of data re-collection. Disciplines are often involved in more than one view as either a provider or consumer of information. Our goal is to involve both internal and external roles as both providers and consumers of the same information so that data does not have to be re-created and that the authoritative source is the true provider of the information.</td>
</tr>
<tr>
<td>D Change Management</td>
<td>Change Management identifies a methodology used to change business processes that have been developed by an organization. If a business process is found to be flawed or in need of improvement, one institutes a “root cause analysis” of the problem and then adjusts the business process based on that analysis. Since this is related to the following item, business processes, it should come after it.</td>
</tr>
<tr>
<td></td>
<td>4 Models for determining the BIM maturity</td>
</tr>
<tr>
<td>---</td>
<td>-----------------------------------------</td>
</tr>
<tr>
<td>E</td>
<td><strong>Business Process</strong>&lt;br&gt;The business process defines how business is accomplished. If the data and information is gathered as part of the business process then data gathering is a no-cost requirement. If data is gathered as a separate process then the data will likely not be accurate. The goal is to have data both collected and maintained in a real time environment, so that as physical changes are made they are reflected for others to access in their portion of the business process.</td>
</tr>
<tr>
<td>F</td>
<td><strong>Timeliness/Response</strong>&lt;br&gt;While some information is more static than other information, it all changes, and up to the minute accuracy may be critical in emergency situations. The closer to accurate real time information you can be the better is the quality of the decisions that are made. Some of those decisions may be life-saving in nature.</td>
</tr>
<tr>
<td>G</td>
<td><strong>Delivery Method</strong>&lt;br&gt;Data delivery is also critical to success. If data is only available on one machine, then sharing can not occur other than by email or hard copy. In a structured networked environment if information is centrally stored or accessible then some sharing will occur. If the model is a systems-oriented architecture (SOA) in a web-enabled environment, net centricity will occur and information will be available in a controlled environment to the appropriate players. Information assurance must be engineered into all phases.</td>
</tr>
<tr>
<td>H</td>
<td><strong>Graphical Information</strong>&lt;br&gt;Often the starting point is a non-graphical environment. The advent of graphics helps paint a clearer picture for all involved. As standards are applied, information can begin to flow as the provider and receiver must have the same standards in place. As 3D images come into play more consumers of the information will have a common view and a higher level of understanding will occur. As time and cost are added, the interfaces can be expanded significantly.</td>
</tr>
<tr>
<td>I</td>
<td><strong>Spatial Capability</strong>&lt;br&gt;Understanding where something is in space is important for many information interfaces and the richness of the information. Energy calculations must know where the heat gains will come from, first responders need to know where water supplies and utility cut-offs are located in relation to the facility.</td>
</tr>
<tr>
<td>J</td>
<td><strong>Information Accuracy</strong>&lt;br&gt;Having a way to ensure that information remains accurate is only possible through some mathematical ground truth capability. Having a mathematical product will also allow for better management by supporting difficult to game metrics. These numbers can be used for occupancy, information collection completeness and overall inventory calculations.</td>
</tr>
</tbody>
</table>
Our ultimate goal is to ensure interoperability of information. Getting accurate information to the party requiring the information. There are many ways to achieve this, however the most effective is to use a standards-based approach to ensure that information is in a form which allows it to be shared and products are available that can read that information standard.

**Table. 11. NBIMS CMM categories**

The last worksheet, which is titled Matrix Definition, defines the particular level of maturity in more detail. The user can read off from it the current level of maturity of the company or project. The following table shows the definitions for categories A and K as examples. The categories B to J are not shown.

<table>
<thead>
<tr>
<th>Category description</th>
<th>Maturity</th>
<th>A Data Richness</th>
<th>K Interoperability / IFC Support</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Choose this selection when you have established a BIM, but have only very basic data load</td>
<td>There is no interoperability between software programs. Information is reloaded for each application</td>
</tr>
<tr>
<td></td>
<td></td>
<td>As you become more advanced, additional data will be available and be entered. This is still early in the maturity</td>
<td>There is some interoperability but it is not automatic or seamless. Information may be cut-and-paste at this level of maturity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>At this point you are beginning to rely on the model for basic data</td>
<td>There is some machine-to-machine flow of information but it is not common or the norm; it is still the exception</td>
</tr>
<tr>
<td></td>
<td></td>
<td>This is the first stage when data is turned into information</td>
<td>Information is flowing between COTS products, often by using products from the same vendor. The Interfaces are likely to be proprietary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The data is beginning to be accepted as authoritative and the primary source</td>
<td>At this level of maturity, information is transferred between COTS products typically from the same vendor, but not all applications are supported</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Some metadata is stored and information is typically best available</td>
<td>There are good machine-to-machine linkages at this level of maturity and information interoperability is the norm</td>
</tr>
</tbody>
</table>
Most users rely on information as reliable and authoritative; little additional data checking is required

Industry Foundation Classes are used on a limited basis for interoperability with some software packages

The information has metadata and authoritative source

IFC use is becoming more commonplace yet is still often used less than other approaches

Limited Knowledge Management implies that KM strategies are in place and authoritative information is beginning to be linked

IFC use is the norm, but not exclusively used to attain interoperability. One would expect about 70-90% IFC-based interoperability

Full Knowledge Management implies a robust data-rich environment with virtually all authoritative information loaded and linked together

At this level of maturity, IFCs are fully implemented and used for interoperability

Table 12. Maturity levels based on the examples of 2 NBIMS CMM categories

The Interactive Maturity Model worksheet contains the Interactive CMM (I-CMM). In column D (Choose your perceived maturity model) there is a drop-down menu which lets the user select the maturity levels for the Areas of Interest listed in column A. The Areas of Interest are the previously described categories. The contents of column C are defined in the Area of Interest Weighting worksheet.

Fig. 24. The I-CMM (NBIMS, 2012b)
The selection options in column D correspond to the contents of the cells in the Tabular Maturity Model worksheet. The difference between the CMM and I-CMM is that the user is shown the maturity level in the form of a points score. The points from the 11 categories are added together in the Credit Sum cell. The evaluation system comprising the following gradings covers a range of 0 to 100 points (NBIMS, 2012b):

- 0 to 19.9 → Not Certified
- 20 to 59.9 → Minimum BIM
- 60 to 69.9 → Certified
- 70 to 79.9 → Silver
- 80 to 89.9 → Gold
- 90 to 100 → Platinum

In the Area of Interest Chart worksheet, the points from column E are shown as percentiles in a radar picture.

Areas of Interest and their Respective Credits

![I-CMM radar picture](NBIMS, 2012b)
The descriptions in the cells of the Tabular Maturity Model worksheet should equally be regarded as the BIM minimum requirements according to NBIMS 2007 and 2012 (McCuen, 2013). The categories were not altered between the 2007 and 2012 versions (NBIMS, 2012a, 2007). CMM was originally developed for evaluating a software process at the Carnegie Mellon Software Engineering Institute (SEI) (Eadie et al., 2012).

4.2.3 BIM level or evolutionary BIM ramp

The evolutionary BIM ramp is used in Great Britain. It was presented in 2008 as part of a case study by Bew and Richards. The case study was an investigation into the development of model-based concepts and their use in digital construction over the last 20 years. The key objective was to determine the changes that have affected construction projects as a result of the digital revolution and the use of BIM software. In order to be able to answer this, 4 construction sector projects were investigated in Great Britain. The individual projects were allocated to different BIM levels (maturity levels) based on the digital technologies used in them. The projects concerned were Endeavor House, Heathrow Express, and Basingstoke Festival Place, which were allocated to BIM level 1, and the Enfield town centre project in London for BIM level 2. Since the focus was on measuring the progress or evolution that had taken place, no project was used to illustrate BIM level 0. Also it was not possible to find a suitable project for BIM level 3 (Bew et al., 2008). The case study investigations enabled improvements in project workflow to be identified and maturity levels to be defined. The defining of them enables the BIM maturity level of a company or project to be determined. (Underwood and Bew, 2009).

The following graphic shows a modified form of the BIM levels according to Bew and Richards' 2008 study (Graham, 2012).
Maturity level 0 is not identified as BIM. (Bew et al., 2008). The evolutionary BIM ramp identifies simple CAD (Computer Aided Design) as maturity level 0. In this phase CAD serves as a digital substitute for a technical drawing board. The object is described using lines and curves in 2D. These drawings cannot be expected to incorporate any intelligent features. Information is generally exchanged via paper plans (Isikdag et al., 2012). The following table provides a more detailed description of the individual maturity levels according to Bew and Richards (Underwood and Bew, 2009; Yusuf, 2014)

<table>
<thead>
<tr>
<th>Maturity</th>
<th>Maturity Description</th>
<th>Modeling type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0</td>
<td>Unmanaged CAD probably 2D, with paper (or electronic paper) as the most likely data exchange mechanism</td>
<td>Use of paper as the most probable data exchange mechanism</td>
</tr>
</tbody>
</table>
### Models for determining the BIM maturity

<table>
<thead>
<tr>
<th>Level 1</th>
<th>Managed CAD in 2 or 3D format using BS1192:2007 with a collaboration tool providing a common data environment, possibly some standard data structures and formats. Commercial data managed by standalone finance and cost management packages with no integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 2</td>
<td>Managed 3D environment held in separate discipline “BIM” tools with attached data. Commercial data managed by an ERP. Integration on the basis of proprietary interfaces or bespoke middleware could be regarded as “pBIM” (proprietary). The approach may utilise 4D programme data and 5D cost elements as well as feeding operational systems</td>
</tr>
<tr>
<td>Level 3</td>
<td>Fully open process and data integration enabled by “web services” compliant with the emerging IFC / IFD standards, managed by a collaborative model server. Could be regarded as iBIM or integrated BIM potentially employing concurrent engineering processes</td>
</tr>
</tbody>
</table>

**Table 13. Meaning of the maturity levels**

The maturity levels were first mentioned in 2011 in the BIM Working Party Strategy Paper (cf. Section 3.4.1.2). The descriptions of the maturity levels are identical to those shown in the previous table (BIM Industry Working Group, 2011).

In the Government Construction Strategy dated 2011 and 2012 the introduction of collaborative 3D BIM by 2016 is described as the goal for all governmental construction projects. The term BIM level 2 is not used for collaborative 3D BIM. In the Government Construction Strategy published in 2012 the term BIM level 3 is only mentioned in relation to the accord with buildingSMART US (see Section 2.3.1.1) (Cabinet Office, 2012, p. 16, 2011, p. 14,16).

In the 'Growth through BIM' report published by the Construction Industry Council (CIC) in 2013, BIM levels 0 to 3 are described using the evolutionary BIM ramp. The report states that the government would like to achieve the maximum possible growth effect through the introduction of BIM. This is done by adding the missing standards, guidelines, classifications (Uniclass) and ISO standards (hereinafter referred to as bodies of rules) for BIM level 2, and by
developing new bodies of rules for the introduction of BIM level 3. The maturity model is intended improve the British construction industry's understanding of the necessary processes, tools and techniques (BIM Industry Working Group, 2011). The bodies of rules that are diagrammatically represented (Saxon, 2013). The next graphic shows in diagrammatic form the additions and enhancements that are needed to achieve BIM levels 2 and 3 (own Illustration according to Bew, 2008; BIM Industry Working Group, 2011; de Groot, 2013).

![Diagram of BIM maturity levels]

**Fig. 27. Required standards, guidelines and interfaces**

Level 1 describes the use of 2D and 3D information as part of digital project execution. Typically, 3D software is used for conceptual design in the early project phases, e.g. for visualisation and further checks or reports (e.g. clashes) using proprietary software. At this maturity level, 3D information is already...
managed in a collaborative manner. (Underwood and Bew, 2009). An important new process is information management. This is embedded in BS 1192:2007 (Collaborative production of architectural, engineering and construction information). The process is supported by Avanti Architects and the Construction Project Information Committee (CPIC). Further improvements are being made to the standards mentioned in connection with BIM level 1 (Jayasena and Weddikkara, 2013; RIBA, 2012, p. 3).

Level 2 requires the use of 3D information models. These models must not exist alongside each other, rather they must form one single model. The intention is to make it possible to apply BS 1192: 2007. Although the contract documentation is assumed to contain defects, legal and contractual aspects and services (BIM Manager) are not considered.

The transition to level 3 is seen as the greatest challenge since it requires integrated BIM (iBIM). This means full software interoperability and cooperative use of the information. The transition is compared to the changeover from hand drafting to CAD (RIBA, 2012, p. 4,5). Level 3 is subdivided into delivery stages A to D (HMG, 2015, p. 24)

The bodies of rules referred to in the previous graphic are crucial to the achievement of the next BIM level. Without their development, the accomplishing of a given level or the achieving of the next level is not possible (BIM Industry Working Group, 2011, p. 42).

The following table describes the individual bodies of rules (own Table according to BIM Industry Working Group, 2011; Bryan, 2013; BSI, 2015b; Waterhouse, 2011)
### Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

#### 4 Models for determining the BIM maturity

<table>
<thead>
<tr>
<th>Level 0</th>
<th>Standards</th>
<th>Guides</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BS 8541-2:2011 Library objects for architectural, engineering and construction</strong></td>
<td>Will offer guidance on the design management to deliver the process and data requirements of BS 1192 and those specified in BS 7000:4</td>
<td></td>
</tr>
<tr>
<td><strong>BS 1192:2007 Collaborative production of architectural, engineering and construction information</strong></td>
<td>BIP 2207 Building information management. A standard framework and guide to BS 1192</td>
<td></td>
</tr>
<tr>
<td><strong>BS 7000-4:2013 Design management systems. Part 4. Guide to managing design in construction</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level 1</th>
<th>Standards</th>
<th>Guides</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BS 1192-4:2014 Collaborative production of architectural, engineering and construction information</strong></td>
<td>Will offer guidance on the design, data management and the workflow processes to deliver the CAPEX &amp; OPEX standard. The requirements and content as defined in the ‘Delivery’ documents to be produced by CPI/Avanti. These will contain the coordinated deliverable of each</td>
<td></td>
</tr>
<tr>
<td><strong>PAS 1192-2:2013 Specification for information management for the capital/delivery phase of construction projects using Building Information Modelling</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PAS 1192-3:2014 (Corrigendum No. 1) Specification for information management for the operational phase of assets using Building Information</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level 2</th>
<th>Standards</th>
<th>Guides</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BS 1192-4:2014 Collaborative production of architectural, engineering and construction information</strong></td>
<td>Will offer guidance on the design, data management and the workflow processes to deliver the CAPEX &amp; OPEX standard. The requirements and content as defined in the ‘Delivery’ documents to be produced by CPI/Avanti. These will contain the coordinated deliverable of each</td>
<td></td>
</tr>
</tbody>
</table>
4 Models for determining the BIM maturity

<table>
<thead>
<tr>
<th>Level 3</th>
<th>Modelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO 16739:2013 Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries</td>
<td></td>
</tr>
</tbody>
</table>

As maturity level 3 becomes a reality and technologies develop into web services and distribution of interoperable data sets, a Level 3 Guide will be developed.

Table 14. Bodies of rules for the BIM levels

Uniclass version 2015 was published as a successor to the existing definition Uniclass 1997. It is an enhancement of Uniclass 2. This conforms to ISO 12006-2 and is compatible with BIM level 2, (CPI, 2015; Designing Buildings Wiki, 2015; NBS, 2011) as well as for all the phases of a project life cycle (Delany, 2015).
Official and binding standards issued by governmental institutions are needed for the evolution of BIM in Great Britain, and already existing ones are also fundamental (BIM Industry Working Group, 2011; BSI, 2013a). The subdivision of BIM levels (Bew et al., 2008), the achieving of BIM level 2 by 2016 (Cabinet Office, 2011), and improvement to BIM Level 3 should be regarded as an evolution and categorisation of maturity levels that are specific to the British construction industry. Furthermore, they require the correct application of the bodies of rules. These have likewise for the most part been developed for Great Britain. Self-testing of the BIM level in a project or company is only possible to a limited extent (Succar, 2015).

In 2014 NBS published the National BIM Report. According to a survey in this document, 95% of those questioned will be using BIM in 5 years' time. It is therefore assumed that the British construction industry is currently at level 0 or level 1 (NBS, 2014b).
4.3 Non-public sector: BIM QuickScan

In 2009 TNO (toegepast-natuurwetenschappelijk onderzoek) (wikipedia, 2013), the largest organisation for applied scientific research in the Netherlands, developed an online questionnaire as a BIM evaluation tool for the Netherlands (Sebastian and van Berlo, 2010). This version of QuickScan is structured in two distinct parts. The first part of the version is divided into four sections or categories:

- Organisation and management,
- Mentality and culture,
- Information structures and workflows,
- Tools and technology

The result is a points score for each section on a scale from 0 to 5 (see graphic).

![Average BIM level per chapter](image)

*Fig. 28. Example of the results based on 130 respondents (QuickScan)
(Berlo et al., 2012)*
The second option for visualising the results is the so-called 'aspects'. All the questions in the 4 sections relate to at least one aspect. The separate aspects are as follows: strategy, organisation, resources, partners, mentality, culture, education, information flows, open standards, tools. The evaluation of the aspects is depicted in a radar picture. The number of individual aspects corresponds to a percentage, with 100 being the maximum value. This provides an overview of the strengths and weaknesses of a company's BIM services (Berlo et al., 2012).

Fig. 29. Radar picture of the aspects based on 130 respondents (QuickScan) (Berlo et al., 2012)

The online BIM QuickScan questionnaire depicts a company's BIM maturity level. An evaluation only works for companies which already use BIM. The questions can be answered either on a self-scan basis or a QuickScan basis (with a certified adviser). In the period from 2010 to 2012 TNO recorded 130 QuickScans and 680 self-scans. The questionnaire is also used in Denmark.
and Australia. The calculation is carried out using an algorithm that has been developed by TNO. (Berlo, 2013).

4.4 Overall conclusion

The models highlighted here are used to assess the BIM maturity level. These models can generally be used without restriction for determining the maturity level. The IU BIM proficiency matrix has been used since 2009 for evaluating BIM expertise. If a construction company wishes to undertake renovation or refurbishment work at IU, it must prove its expertise by completing the BIM proficiency matrix. A total of 50 construction firms have been approved for working with IU. The British maturity model is very specific and is linked to country-specific as well as ISO standards. It is used for describing the further development of BIM in conjunction with the required standards in Great Britain rather than for assessing the BIM maturity level in an institution or within a project. The ISO standards can of course be used following any adaptations to them that may be made at the national level. Countries where there is still no detailed underlying development process can participate in this model. It should be recognised that a basic knowledge of BIM is a prerequisite for any maturity model. This can lead to complications in the case of self-assessments. The questions involved in determining the maturity level may be answered incorrectly, or not at all, incorrect due to a lack of knowledge. The TNO model is unique in this aspect. In the case of the TNO QuickScans an auditor is responsible for ensuring that the right questions are asked. If questions are raised he can also provide assistance which helps support correct and precise answers. The issue of sustainability is not dealt with in any of the models for determining the BIM maturity level.
5. Interoperability

5.1 Definition

Interoperability eases the integrated and error-free use of digital information technology in the construction field. It is the foundation of digital communication (McGraw Hill, 2007). The basis of this communication is an interface. There may, for instance, be a number of technical specifications for an interface. There may also however be a number of rules stipulated by a software vendor which are accepted either implicitly or on the basis of an agreement (David and Greenstein, 1990). If this interface is defined by just one software, the exchanging of information between all the parties involved in a project throughout its life cycle is usually only possible within this one software (cf. Section 2.4). In this case, proprietary formats are used for the exchanging of information (wikipedia, 2015b). A proprietary interface favours decentralised storage of the digital information. Furthermore, the exchanging of information is generally restricted to graphical information (Björk and Penttilä, 1989). A building information model contains more than just graphical information (cf. Chapter 1). In order to achieve the interoperability which is necessary for BIM, a non-proprietary interface must be provided (Sullivan and Keane, 2005).

5.2 Interoperability in public construction sector

The building information model should be viewed as a knowledge or information base. It makes all the relevant information relating to all the project phases centrally accessible and available for collaborative use. Interoperability and a non-proprietary standard make the aforementioned knowledge or information base available to all parties. The tools-specific model and the information-specific model are derived from this approach.

The tool-specific model provides decentralised storage of the information. Every tool contains specific information which is related to other necessary information. However, due to a lack of interfaces it is not possible to
automatically link the information. Individual information islands arise which are linked to each other via proprietary interfaces.

In the case of the information-specific model, the information flows, together with all the related digital information, are managed via a non-proprietary interface based on a single central, interoperable model. Duplication is eliminated and the specific decision-making criteria are provided efficiently and without any errors.

Interoperability is the ability to exchange information contained in two or more systems or components and to make error-free use of it. Information is collated to form a BIM. This enhances correct communication throughout the life cycle of the building. It also reduces duplication, and efficiency is increased (Grilo and Jardim-Goncalves, 2010; Laakso and Kiviniemi, 2012).

There now follows an investigation into the non-proprietary, interoperable IFC interface. This is used in public construction sector throughout the world. The
findings relating to the use of this interface in public construction sector are derived from Chapter 3. This statement is also supported by a variety of international sources (Malleson et al., 2013, p. 7; McGraw Hill, 2014c, p. 19; NBS, 2014b, p. 16). IFC is the only holistic, non-proprietary standard for exchanging building information model which is international accepted and operates on a non-proprietary basis (Liebich, 2010, p. 1).

5.3 IFC

In 1994, 12 US companies established the Industry Alliance for Interoperability. The aim was to develop an interoperable interface. The initial group of companies was as follows (Kiviniemi, 2006):

- Autodesk,
- Archibus,
- AT&T,
- Carrier Corporation,
- Hellmuth, Obata & Kassabaum Architects (HOK),
- Honeywell,
- Jaros Baum & Bolles,
- Lawrence Berkeley Laboratory,
- Primavera Software,
- Softdesk Software,
- Timberline Software,
- Tishman Construction.

After a year of collaboration, the companies came to the decision that (buildingSMART, 2008):

- interoperability is important and offers great public potential,
- this interface must be open and international,
- it must not be private or proprietary,
- and any party which wants to be involved in its development should be able to become a member.
Based on these conclusions reached by the consortium which was then in place, in 1996 the Industry Alliance for Interoperability was renamed in International Alliance for Interoperability. This made it possible for any interested parties to become members of it (wikipedia, 2015c). In 2008 the name was changed once more. Now the organisation is called buildingSMART. This step was taken in order to better reflect the aims of the consortium. It is the view of the consortium that 'building' refers to the entire construction field. SMART stands for intelligence, interoperability and teamwork (buildingSMART, 2008). The IFC Initiative began in 1994 (wikipedia, 2015d).

BuildingSMART comprises a central organisational unit. This has the suffix 'international' in its title. The organisational units below it are divided into country groupings. These are the so-called 'chapters'. In 2014 buildingSMART comprised a total of 17 chapters, for the following country groupings (buildingSMART, 2015b):

- Australasia,
- Benelux,
- Canada,
- China,
- Finland
- France,
- Germany,
- Hong Kong,
- Italy,
- Japan,
- Korea,
- Malaysia,
- Nordic,
- Norway,
- Singapore,
- Spain,
- UK & Ireland,
5 Interoperability

5.3.1 From STEP to IFC

In 1984 work began on STEP (STandard for the Exchange of Product model data). In order to carry out this work, ISO set up its Technical Committee TC184 and sub-committee SC4 (Eastman, 1999, p. 129). This standard used new findings from and developments in the information modelling of the time as well as data structure definitions (Wix and Nisbet, 2008). The intention was to develop a comprehensive standard for the electronic exchanging of product information between computer-based product life cycle systems in the automotive, aviation and mechatronic sectors (Prasad, 2000). The STEP model is independent of the product class or industry. Major automotive manufacturers use different digital information to that used by smaller suppliers of standard parts (Zheng and Possel-Dölken, 2013, p. 149). The development of this standard was one of largest tasks undertaken by ISO. The STEP Standard that was developed was published in 1994 as ISO 10303. ISO 10303 covered a wide range of different product types and life cycle stages. It contains a large number of parts. These are referenced under ISO 10303 – AP XYZ: XYZ denotes the parts, and AP stands for Application Protocol (Pratt, 2001). An AP encompasses the definition, the context and the information requirements of the respective sector of industry, and it is applicable to one or more life cycle stages of a specific product class. The APs use Integrated Resources (IRs). IRs define the basic semantic elements for describing any given product at any given phase of its life cycle. IRs make it possible to represent a single, specific product. Each one contains a number of product descriptions. An IR is subdivided into 2 categories. Both categories are shown in the following table. This is not intended to provide an exhaustive list.

<table>
<thead>
<tr>
<th>Integrated Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generic Resource Models</td>
</tr>
<tr>
<td>Part 41 Fundamentals of Product Description and Support</td>
</tr>
<tr>
<td>Application Resource</td>
</tr>
<tr>
<td>Part 101 Drafting Resources</td>
</tr>
</tbody>
</table>
The first category is GR (Generic Resources). This contains models which are not associated with any specific context of use.

The second category is AR (Application Resources). This contains models which are associated with a context of use, or with a class that can be assigned to a particular sector of industry.

The GRs are used as basic information, and they are independent of their use and may be interrelated. The ARs relate to the GRs, and they add further specifications for a specific application. An AR may refer to a GR, but not to itself. An AP consequently uses the IRs as the basis for the definition and specification of the products (Nishijima, 1997, p. 91; Prasad, 2000, p. 391; STEP, 2015; Underwood, 2009, p. 109; Wang, 1999; Xun, 2009, p. 248).

The following graphic provides a simplified diagrammatic representation of how APs use the IRs. The referencing between the GRs and ARs is also shown (Nishijima, 1997, p. 93).
Some of STEP AP parts are regarded as being especially important within the AEC sector. Specifically these are (Dincer, 2008; Eastman, 2008, p. 72; Santos et al., 2002; Wix and Nisbet, 2008):

- AR 106 Building Construction Core Model (BCCM)
- AP 225 Building Elements using Explicit Shape representation
- AP 228 Building Services – HVAC
- AP 230 Building Structural Frame – Steelwork

Fig. 31. Simplified structure of the STEP model
(Nishijima, 1997, p. 93)
5 Interoperability

- AP 236 Furniture Catalogue and Interior Design
- AP 241 Generic Model for Life Cycle support of AEC Facilities

The overall structure of the STEP standard is as follows (Wang, 1999, p. 24):

- Parts 1-9 Introductory
- Parts 11-19 Product Data Description Methods
- Parts 21-29 Implementation Methods
- Parts 31-39 Conformance Testing Methodology and Framework
- Parts 41-49 Integrated Resources: Generic Resources
- Parts 101-199 Integrated Resources: Application Resources
- Parts 201-1199 Application Protocols
- Parts 1201-2199 Abstract Test Suites

Based on ISO's existing recognition of STEP, in 1994 the development of the IFC standard was started on the basis of the STEP standard (IAI, 2000, p. 39). In addition, other existing technologies were also used for developing the IFC standard:

- the EXPRESS programming language, ISO 10303-11 (van and Timmermans, 2006, p. 450),
- parts of the STEP IR,
- the implementation methods

AR 106 was used as the basis for developing the IFC Object Model. (Underwood, 2009, p. 110).
5.3.2 IFC 1.0 and 1.51

The first version, IFC 1.0, was published in January 1997. Its scope was very limited and was restricted to geometrical aspects.

In addition, it represented the HVAC, plumbing systems and facility management and construction processes (Kiviniemi, 1999). This version was used for exchanging prototypes so as to achieve a robust version of IFC 1.5. 17 companies were involved in the testing of prototypes (Laakso and Kiviniemi, 2011; Liebich and Wix, 2003).
IFC 1.5 was released in November 1997. Due to implementation problems experienced by the commercial software producers, version 1.51 was released as early as 1998 and was successfully implemented and used in the construction software field (Laakso and Kiviniemi, 2012).

![Architecture of IFC 1.5](Kiviniemi, 1999)

Version 1.51 was considered not be suitable for the exchanging of information. This was due to the following reasons (Backas, 2001, pp. 8–10):

- A lack of IFC-specific documentation, such as guides and manuals.
- The loss of information during handover.
- Distortion of the geometry.
- IFC file size too large compared to the native format.
- Management and use of the object-oriented information relating to a component in the 3D model is not possible.
- Differing modelling practices:
  - What information is needed for each project stage?
  - What is the digital information needed for within the model (costs estimation, energy simulation)?

Fig. 34. Example of the distortion of the geometry
(Pazlar and Turk, 2008)

The plan was to bring out a new, improved version of IFC every year. However, this was not possible for financial reasons (Laakso and Kiviniemi, 2011). One reason is that the development cycle of an IFC version contains a total of 9 development steps (Liebich and Wix, 2003).
5.3.3 IFC 2.0 to 2x3

Version 2.0 was released in 1999. Its scope was extended through the incorporation of diagrams relating to building management systems, costs estimates, and construction planning (Liebich, 2010). Development costs for IFC version 2.0 were approximately $400,000 (Laakso and Kiviniemi, 2012). Due to the many and varied possible uses of an IFC model and the fact that the entire IFC structure cannot be completely used or represented in any project, a model view for the IFC classes was defined through a project called BLIS (Building Lifecycle Interoperable Software). BLIS was an autonomous organisation, but it did offer membership to existing IAI participants. The BLIS organisation focused particularly on software producers in order to assist them with implementation into the commercial systems. BLIS attempted to show the relationships between the individual IFC classes by using a concept model which was defined in terms of practical information exchange applications (Hietanen, 2000; Laakso and Kiviniemi, 2011).

Fig. 35. New processes in IFC 2.0

BLIS was used to specify the Model View Definitions (MVD) (MacPherson, 2009). Figure 35 shows the new processes contained in version 2.0 (IAI, 1999). The MVD concept is explained in the following sections.
At the same time, fundamental problems were identified regarding the structure, modularity and extensibility of the schema of the architectural model. This realisation leads to the release of IFC 2x platform.

The successor versions are shown in the following table (Liebich, 2010).

<table>
<thead>
<tr>
<th>Release</th>
<th>main achievements</th>
<th>published</th>
<th>main purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
<td>major extension of scope, fully attributed view (and other improved documentation)</td>
<td>May 1999</td>
<td>scope extension</td>
</tr>
<tr>
<td>2x</td>
<td>major rework for modularity, new documentation format, first ifcXML schema in XSD</td>
<td>Oct 2000</td>
<td>stability release</td>
</tr>
<tr>
<td>2x add1</td>
<td>minor bug fixes and documentation improvements, submitted to ISO as ISO/PAS16739</td>
<td>Oct 2001</td>
<td>minor corrections</td>
</tr>
<tr>
<td>2x2</td>
<td>major extension of scope, first ISO-compliant ifcXML schema in XSD</td>
<td>May 2003</td>
<td>scope extension</td>
</tr>
<tr>
<td>2x2 add1</td>
<td>minor bug fixes and documentation improvements</td>
<td>Jul 2004</td>
<td>minor corrections</td>
</tr>
<tr>
<td>2x3</td>
<td>stability and improvements, better implementation guidance</td>
<td>Feb 2006</td>
<td>stability release</td>
</tr>
<tr>
<td>2x3 TC1</td>
<td>minor bug fixes and documentation improvements</td>
<td>Jul 2007</td>
<td>minor corrections</td>
</tr>
</tbody>
</table>

Table 16. Releases of IFC from 2.0 to IFC 2x3

Since the introduction of the 2x platform it has also been possible to store the IFC files as an XML file. This make it possible to exchange IFC files furthermore in the form of an XML file. (Begley et al., 2005). The use of the XML format has resulted in improved compatibility and better collaboration within the construction industry. Interoperability of the IFC interface has been further enhanced through the use of the XML technology. The use of IFC XML is defined according to ISO 103030-28 due to its standardisation as a STEP XML (Akin, 2011, p. 131).
The extensions contained in the 2x version compared to 1.5.1 are shown in the following graphic (IAI, 2000).

Fig. 36. Developments of IFC 1.51 to 2x

IFC versions 1.5.1 and 2.0 were mainly used in research projects or in a few commercial pilot projects. Only from 2005 onwards was increased pressure exerted on the developers by public sector clients (GSA, Senate Properties and Statsbygg). IFC 2x3 is consequently the first IFC version which has been implemented in over 100 software applications. Its use under real conditions led
to the following interoperability requirements for the implemented IFC version (Liebich, 2010):

- Simpler use of the export and import options for the end user through the provision of guidelines and help files.
- New certification procedure for improving the software implementations.
- More comprehensible implementation guidelines provided by Model View Definition (MVD).
- Improved presentation of the documentation for the entire IFC hierarchy (IFC specification).

In 2002 the IFC standard was likewise supported by TC184, and it was declared to be a ISO/PAS 16739. This was due not least to the fact that most IAI members were also involved in the establishing of STEP. (Smith, 2008; Underwood, 2009, p. 110). In addition, the core parts of IFC were integrated into a robust version. These are the parts of the STEP standard that were mentioned in Section 5.3.1 (cf. ISO, 2005).

### 5.3.4 IFC 2x4 to 4.0

In its fourth development stage IFC version 2x4 was renamed IFC 4.0 (buildingSMART International, 2015a):

<table>
<thead>
<tr>
<th>Release</th>
<th>Type</th>
<th>Published</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0</td>
<td>officially released</td>
<td>March 2013</td>
</tr>
<tr>
<td>2x4</td>
<td>Release Candidate 4</td>
<td>September 2012</td>
</tr>
<tr>
<td>2x4</td>
<td>Release Candidate 3</td>
<td>October 2011</td>
</tr>
<tr>
<td>2x4</td>
<td>Release Candidate 2</td>
<td>September 2012</td>
</tr>
</tbody>
</table>
Various functions were implemented in the development phases shown in the table. These are described in more detail in the following sections.

While in the case of the previous IFC versions – especially if different specialist planners were involved – it was often difficult to provide an overview of the IFC structure and any such overview was too generalised or unintelligible, MVD (Model View Definition) was incorporated into IFC version 4.0 (buildingSMART, 2015b). This defines one or more of the required subsets of the IFC schema and therefore fulfils technical exchange requirements (buildingSMART German Speaking Chapter, 2015). The MVDs can be produced using the ifcDoc tool and then forwarded to the specialist planners who are involved in the project (buildingSMART International, 2015b).

In addition, TC59 SC13 developed ISO standard 12006-3 (Building construction - Organization of information about construction works - Part 3: Framework for object-oriented information), which forms the basis of the International Framework for Dictionaries (IFD). The IFD is an open semantic construction terminology database. Specifically, it is a lexicon which contains definitions for object-oriented product information (ISO, 2007; Loureiro and Curran, 2007, p. 530; Teller et al., 2007). This lexicon provides various descriptions and specifications for objects in different languages. Activities, characteristics, units, measures and parties involved are also objects in the context of ISO 12006-3.
The next component to be developed was the Information Delivery Manual (IDM). This describes at least two different software applications as well as the information that is exchanged between these applications. An IDM consequently contains information on the following components:

- Description of the industry process in which the sharing is to take place (architecture, HVAC, etc.)
- Requirements and definitions relating to the scope of the information that is to be shared / the models
- System specification (exchange requirements model according to the industry, e.g. architecture, HVAC, etc.)

With the help of the IDM, the MVD can also be used to undertake an structured review of the exchange process. The information in the IDM and the MVD help to clarify the information sharing scenario within the IFC model (Ole Berard, 2012; Wix, 2007). The IDM is based on ISO 29481-1 and -2 (Tomanová, 2015).
In July 2008 IFC 2x4 was submitted to ISO for review. The aim was to make the version a fully adequate ISO standard (Smith, 2008). This happened in 2013 (ISO, 2013). The following graphic shows the interrelationships between the components that have been described above (ISO 12006-3 (IFD), and the IDM and IFC) (buildingSMART International, 2015c).

The central innovations in IFC 4.0 are (Liebich, 2013b, 2010, p. 5):

- the most important IFC specifications, such as architecture, building management systems and statics elements, have been supplemented with new geometric and parametric information,
- numerous new BIM views:
  - exchanging of 4D and 5D information,
  - product libraries,
  - BIM has been enhanced with GIS interoperability,
  - improved thermal simulations and sustainability assessments
- improved legibility and simplified access to the documentation, including numerous implementation concepts and linked examples (MVD),
• the ifcXML4 schema, like the EXPRESS schema, is fully integrated into the IFC description,
• technical problems which have been found since the release of IFC2x3 have been fixed,
• it enables the IFC infrastructure to be extended.

As described above, IFC 4.0 was released in 2013. Before a software vendor implement the versions, they have to be certified via a specified buildingSMART procedure (buildingSMART International, 2015d). Currently IFC 2x3 is used as the stable version. (Gupta, 2013, p. 68; wikipedia, 2015e). The IFC 2x3 architecture is therefore described below.

The architecture of the IFC 2x3 model is based on the following 4 layers:

• Domain layer.
• Interoperability layer.
• Core layer.
• Resource layer.

There are strict reference hierarchies for the layers. A reference can only be made to a lower level. The architecture of the layer structure is shown in the following graphic (buildingSMART International, 2007). The job of each layer is explained in the next section with the aid of the following graphic and then in written form (Anumba et al., 2006, p. 152; Clemen and Gründig, 2006, p. 2; Froese and Yu, 1999, p. 3; IAI, 2000, pp. 7–11; Laakso and Kiviniemi, 2012, p. 144; Rio et al., 2013, p. 221).
The domain layer defines the information contained within a specific field of the construction industry (domain). This layer therefore provides a series of modules from the specific fields within the construction industry. The domain layer organises them according to the type of company / method of execution (architecture, HVAC, structural analysis, etc.). Each domain should be regarded as a separate model which uses a class from the core or resources layer.

The interoperability layer provides a plug-in for various domain models. One or more domains from the upper layer can be allocated to the lower layers. The various components of individual domains can consequently use any existing or
identical information relating to other components from the lower layers. The outsourcing of the domain models is likewise supported in the lower layers.

The core layer comprises the kernel and the core extensions. The kernel contains all the basic concepts of the IFC models within the current IFC version. It also specifies the model structure and breakdown (outsourcing). Concepts which are defined in the kernel are abstracted at a higher level. Furthermore, it contains basic concepts about the provision of objects, relationships, type definitions, attributes and roles. The kernel can be viewed as a template (schema) for the breakdown of all the models. The kernel contains the mandatory components of all IFC implementations. It forms the basis of the IFC core model. The classes within the kernel may refer to classes in the resource layer, but not to themselves or higher layers.

The core extensions provide extensions or refinements of the concepts defined in the kernel. Each core extension further refines the classes which are contained in the IFC kernel. It is a type of refinement layer for the abstracted kernel constructs. In addition, relationships and roles are defined through routines. A class which is defined in the core extensions uses inheritances from the interoperability layer or domain layer. However, an inheritance cannot be adopted from the kernel itself or from the resource layer.

The Resource Layer contains various basic concepts. These describe, for instance, geometry (point, line and curve) topology (vertex, edge, surface and shell), 3D models (definition). This layer consequently serves as a descriptive container for the layer above it. Elements from other layers may refer to elements in the resource layer.

For better understanding, the following graphic illustrates the architectural model shown above incorporating IFC entities. This graphic illustrates the description of the layer structure. Due to the large number of classes and entities, the graphic is not intended to provide a full picture. It is not possible to show all the entities due to the large number of them (Stejksal, 2003).
The contents of IFC platform and of the non-platform part are dependent on the IFC version. The stage of development of the IFC platform is frozen when it is officially released. Consequently no changes can be made to it while it is in use. All software producers can implement the stable, official IFC platform. This ensures that no changes occur in the core of the IFC platform. The non-platform part is used for integrating further external functionalities into the respective IFC version. This describes further extended functionalities for the construction industry (e.g. for structural steelwork) (Simmons and Graphisoft, 2003).
The extended functionalities are integrated according to defined principles (Osterrieder and Richter, 2004, p. 15):

- Avoidance of major interventions in the IFC schema so as to ensure that the extensions are integrated quickly
- Entities which are already available in the IFC platform are not integrated
- Compatibility with related construction industry fields must be ensured (e.g. structural steelwork with reinforced concrete and precast concrete components)

The following graphic shows the definitive scope of the content that has been added in the various IFC versions (Wix and Nisbet, 2008).
Fig. 41. Overview of the IFC versions and changes in content (Wix and Nisbet, 2008).
6. Sustainability in the public construction sector

6.1 Development of sustainability awareness

The first written consideration of sustainability can be found in the 17th century Code forestier (French forest management code) The Code forestier applied to the resource of timber and it described the sustainable management of wild arboriculture. The aim was to ensure the long-term use of timber in a qualitatively unchanging manner while taking account of ecological and economic considerations. (Lützkendorf et al., 2009).

Much later, the United Nations Environment Program (UNEP) together with the World Wildlife Fund (WWF) developed the World Conservation Strategy (WCS). This strategy prepared the way for the international discussion of sustainability. The involvement of more than 100 countries in developing the WCS laid the foundations for an international approach to sustainability. Based on population trends and the use of renewable resources (e.g. timber, fish etc.) it is made clear that the previous use of finite goods needs to be fundamentally rethought, and that new strategies are required. The WCS consequently provides a global, interdisciplinary approach for assessing sustainability and encourages a change in mindset (UNEP et al., 1980).

The first sustainable development guidelines of the modern era were set out in the 1987 Brundtland report drawn up by the United Nations (Meadows et al., 2012, p. XVI). This report acted as a trigger for further environmental conferences, such as in Rio de Janeiro in 1982. The Brundtland report 'Our Common Future' specifies the following guiding principle of sustainable development, and it consequently creates a new level of awareness regarding the use of renewable resources (Aachener Stiftung Kathy Beys, 2015; Drexhage and Murphy, 2010; UN, 1987).

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”
Agenda 21 was drawn up at the aforementioned climate conference in Rio de Janeiro. In this report 172 countries agreed for the first time to align their actions with the guiding principles of sustainable development (unesco, 2009; wikipedia, 2015f). For the first time, Agenda 21 also specified economic goals for commerce and industry alongside sustainable social and ecological goals (Ebert et al., 2010, p. 19).

6.2 Evaluation of sustainability in construction

Construction is known to make extensive use of raw materials and energy resources. This represents an excessive consumption of resources such as water, raw materials, energy and fossil fuels. As well as the excessive consumption of raw materials, the operation of a building continues to cause the emission of harmful gases such as CO₂. (Ahankoob et al., 2013; ECORYS, 2014). CO₂ emissions are responsible for the global warming. Construction accounts for 40% of worldwide CO₂ emissions. Experts in the construction and real estate industry agree that the number of new buildings will increase by 30% over the next 30 years. This means increasing consumption of the aforementioned resources, and an increase in energy consumption. Sustainability within the construction sector is assured if energy, water and material resources are used efficiently. This should be accompanied by a reduction of harmful by-products such as CO₂ and occur as part of concerted action which takes account of human and environmental factors. Sustainability must consequently be regarded as a holistic process which starts with planning and extends through construction to demolition and / or renovation. All the conceivable life cycles of a building must be considered. The calculatory evaluation of these life cycles produces reliable results which enable the sustainability of a building to be graded. This comprehensive approach has led to the development of evaluation tools for sustainable construction in various countries. Sustainable construction is necessary in order to evaluate and monitor the environmental impacts of economic growth in ecological, economic and socio-cultural terms (Makkie, 2009).
6.3 Sustainable building evaluation systems

The use of these evaluation systems is specified and supported by national and international institutions in the field of construction in the public sector (Hayden et al., 2010). Buildings are certified according to a variety of different sustainability evaluation criteria around the world (CRITERION, 2014). Depending on each country's geographical location, the focus is placed on different evaluation criteria when certifying a building. The following table lists the certification systems that exist around the world, focusing on the field in which the sustainability evaluation is used (FIDIC, 2014). The table is not intended to provide an exhaustive list.

<table>
<thead>
<tr>
<th>Assessment tool</th>
<th>Countries</th>
<th>General civil infrastructure</th>
<th>Applicable sectors</th>
<th>Public realm</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCA Green Mark</td>
<td>Singapore</td>
<td>applicable</td>
<td>applicable</td>
<td>applicable</td>
</tr>
<tr>
<td>BEAM</td>
<td>Hong Kong</td>
<td></td>
<td>applicable</td>
<td></td>
</tr>
<tr>
<td>BERDE</td>
<td>Philippines</td>
<td></td>
<td>applicable</td>
<td></td>
</tr>
<tr>
<td>BREEAM</td>
<td>UK developed. Used throughout Europe + other international applications.</td>
<td></td>
<td>applicable</td>
<td></td>
</tr>
<tr>
<td>CalGreen</td>
<td>California state only, USA</td>
<td></td>
<td>applicable</td>
<td></td>
</tr>
<tr>
<td>CASBEE</td>
<td>Japan</td>
<td></td>
<td>applicable</td>
<td></td>
</tr>
<tr>
<td>CEEQUAL</td>
<td>UK &amp; Ireland version, Hong Kong version, internationally applicable</td>
<td>applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>China Ministry of Construction Green Building System</td>
<td>China</td>
<td></td>
<td>applicable</td>
<td></td>
</tr>
<tr>
<td>Methodology</td>
<td>Country</td>
<td>Applicability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------------</td>
<td>--------------------------------</td>
<td>----------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BNB Sustainable Building Evaluation System</td>
<td>Germany</td>
<td>applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DGNB - the German Sustainable Building Certificate</td>
<td>Germany &amp; International</td>
<td>applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Envision</td>
<td>United States</td>
<td>applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estidama &amp; the Pearl Rating System</td>
<td>Abu Dhabi</td>
<td>applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Building Index</td>
<td>Malaysia</td>
<td>applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Globes</td>
<td>Canada and USA</td>
<td>applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Star (Au)</td>
<td>Australia</td>
<td>applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Star (NZ)</td>
<td>New Zealand</td>
<td>applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Star (SA)</td>
<td>South Africa</td>
<td>applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GreenLITES</td>
<td>New York State, US</td>
<td>applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greenroads</td>
<td>USA - piloting internationally</td>
<td>applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greenship</td>
<td>Indonesia</td>
<td>applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TERI GRIHA</td>
<td>India</td>
<td>applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HQE Amenityment</td>
<td>France</td>
<td>applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydropower Sustainability Assessment Protocol</td>
<td>Globally applicable</td>
<td>applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infrastructure Sustainability</td>
<td>Australia</td>
<td>applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INVEST</td>
<td>USA</td>
<td>applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LEED</td>
<td>Developed in the US, now</td>
<td>applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NABERS</td>
<td>Australia, expanding to New Zealand</td>
<td>applicable</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 18. Evaluation systems around the world

<table>
<thead>
<tr>
<th>NatHERS</th>
<th>Australia</th>
<th>applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBTool (GB)</td>
<td>Europe</td>
<td>applicable</td>
</tr>
<tr>
<td>STAR Community Rating System</td>
<td>USA (primary base) and Canada</td>
<td>applicable</td>
</tr>
<tr>
<td>STARS</td>
<td>USA</td>
<td>applicable</td>
</tr>
</tbody>
</table>

Of the certification systems listed in the table,

- BREEAM (Building Research Establishment Environmental Assessment Methodology),
- LEED (Leadership in Energy and Environmental Design), and
- DGNB (German Sustainable Building Council)

undertake the majority of sustainability assessments worldwide (Luft, 2013; Reed and Krajinovic-Bilos, 2013).

The BREEAM assessment catalogue was published in the United States in 1990. Since then, the institution responsible for it has established numerous sub-offices around the world. This means that BREEAM sustainability certification is possible internationally (BREEAM, 2015). The situation is similar with regard to LEED. It provides sustainability certifications in 76 countries. DGNB, the most recent system, follows the same approach and can equally be used internationally. The following graphic shows the systems in use around the world. The most frequently used sustainability evaluation systems in the construction sector are highlighted in an orange frame (Luft, 2013).
The DGNB certification system is unique in some respects. It originates from the previous system, the Deutsches Gütesiegel für Nachhaltiges Bauen (German sustainable building quality mark). The German sustainable building quality mark was developed by the Federal Ministry for Transport, Construction and Urban Development (BMVBS), and it was verified in various pilot certifications. Following these verifications, the certification system was split into the BNB (Sustainable Building Evaluation System) and the DGNB (Fouad, 2014, p. 75). Since then, BNB has been used exclusively for the sustainability certification of Federal and regional government public buildings, and it has been operated by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). DGNB is used for private investors' building projects (Siebers, 2013). However, due to manner in which they were developed, the content of BNB and DGNB is identical (VDI, 2013).

Experience and findings from existing evaluation systems are incorporated into the development of a new evaluation system. Hence there are clearly identifiable connections between the certification systems (Ebert et al., 2010). The following graphic shows the links between the content of the systems that have been discussed. The graphic clearly shows the influences of the content of the older certification systems as BREEAM and LEED on the more recent
BNB. The listing of the systems is on an historical basis. Other evaluation systems are not highlighted in the graphic since final discussions are being held between BREEAM, LEED and BNB.

```
Fig. 43. Identical content within new sustainability certification systems (own Illustration according to Ebert et al., 2010).
```

Just like the other systems that have previously been discussed, BNB can be used on an international basis. Indeed, BNB actually has a decisive advantage in this regard. The BNB assessment takes the full life cycle into account when considering sustainability (Draeger, 2012). Moreover, BNB is technologically more advanced (VDI, 2013).

This means that when compared to BREEAM, LEED and DGNB, BNB is the only evaluation system which

- is used and developed by a ministry,
• is used without restriction and on a mandatory basis for evaluating sustainability in construction in the public sector,

• does not comprise a registered association or other private sector grouping,

• incorporates a public evaluation methodology and matrix which can be accessed without charge,

• is the most modern and up-to-date system,

• contains the most advanced technology,

• considers the entire life cycle.

For these reasons the BNB sustainability certification system is examined in more detail in the following sections in order to illustrate a solution for the efficient use of the BIM methodology in relation to sustainable construction in the public sector.

### 6.4 BNB: Sustainable Building Evaluation System

The distinguishing characteristic of BNB is its comprehensive consideration of buildings. Using the results-oriented Sustainable Building Evaluation System not only enables individual measures to be quantified, it also records sustainability throughout the building's entire life cycle.

It is from these considerations, together with the goal of protecting common goods such as the environment, resources, health, culture and assets, that the three classic dimensions of sustainability are derived, namely

• ecological,
• economic, and
• socio-cultural aspects.
The quality of a building's sustainability is measured based on these main groups of criteria.

In addition,

- technical quality and
- process quality

are viewed as further main groups of criteria for determining sustainability (BMVBS, 2011).

The evaluation of sustainability according to BNB is based on the above five main criteria groups. The main criteria groups are each assessed in isolation and then evaluated using the weightings shown in the following table which total 100% (BMVBS, 2011).

![BNB main criteria groups and percentage weighting](image)

*Fig. 44. BNB main criteria groups and percentage weighting (own Illustration according to BMUB, 2013b).*
The location profile is not shown in the graphic since it can only be influenced to a limited degree. Although it can be shown as additional information, it is not incorporated into the evaluation percentages (BMUB, 2013b).

The individual evaluation of the main criteria groups enables special services relating to each group to be individually highlighted. The overall evaluation enables an objective and quantified statement to be made regarding sustainability, as well as comparisons with other certified buildings. The five main criteria groups contain 40 criteria. Location profile additional six. A synopsis of the main criteria groups, criteria groups, and criterion for evaluating new-build office, educational and laboratory buildings is shown in the following table. It also shows the relevant life phase, i.e. in which of the building's life cycles the data is relevant, as well as the point in time when the criterion is verified (BMUB, 2014a; BMVBS, 2011). No further examination of the evaluation methods for outdoor facilities is undertaken. The table only relates to new buildings.

<table>
<thead>
<tr>
<th>Sustainability criteria with the main groups of criteria, criteria group and criterion and rating</th>
<th>relevant life cycle phase</th>
<th>Phase of proof</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ecological Quality 22.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1 Effects on Global and Local Environment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1.1 Global Warming Potential (GWP)</td>
<td>Overall</td>
<td>Planning</td>
</tr>
<tr>
<td>1.1.2 Ozone Depletion Potential (ODP)</td>
<td>Overall</td>
<td>Planning</td>
</tr>
<tr>
<td>1.1.3 Photochemical Ozone Creation Potential (POCP)</td>
<td>Overall</td>
<td>Planning</td>
</tr>
<tr>
<td>1.1.4 Acidification Potential (AP)</td>
<td>Overall</td>
<td>Planning</td>
</tr>
<tr>
<td>1.1.5 Eutrophication Potential (EP)</td>
<td>Overall</td>
<td>Planning</td>
</tr>
<tr>
<td>1.1.6 Risks for the local environment</td>
<td>Erection</td>
<td>Tendering and Contracting</td>
</tr>
<tr>
<td>1.1.7 Sustainable Logging / Wood</td>
<td>Erection</td>
<td>Tendering and Contracting</td>
</tr>
<tr>
<td>1.2 Demand of Resources</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Category</td>
<td>Stage</td>
<td>Phase</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>------------</td>
<td>---------------</td>
</tr>
<tr>
<td>1.2.1 Primary Energy Demand not Renewable (PEnr)</td>
<td>Overall</td>
<td>Planning</td>
</tr>
<tr>
<td>1.2.2 Total Primary Demand (PETot) and amount of PEr</td>
<td>Overall</td>
<td>Planning</td>
</tr>
<tr>
<td>1.2.3 Fresh Water Requirements and Quantity of Wastewater</td>
<td>In Use</td>
<td>Planning</td>
</tr>
<tr>
<td>1.2.4 Space Requirements</td>
<td>Erection</td>
<td>Project Development</td>
</tr>
</tbody>
</table>

2. Economical Quality 22.5%

2.1 Life Cycle Costs

2.1.1 Building-related Life Cycle Costs | Overall | Planning |

2.2 Performance

2.2.2 Stability of Value | In Use | Planning |

3. Sociocultural and Functional Quality 22.5%

3.1 Health, Comfort and User Satisfaction

3.1.1 Thermal comfort in winter | In Use | Planning |
3.1.2 Thermal comfort in summer | In Use | Planning |
3.1.3 Indoor Air Quality | In Use | Hand over / In Use |
3.1.4 Acoustic Comfort | In Use | Planning |
3.1.5 Visual Aesthetics | In Use | Planning |
3.1.6 Influence of the User | In Use | Planning |
3.1.7 Building-related Outdoor Qualities | In Use | Planning |
3.1.8 Safety and Incident Risks | In Use | Planning |

3.2 Functionality

3.2.1 Barrier-free Building | In Use | Planning |
3.2.2 Space Efficiency | Overall | Planning |
3.2.3 Conversion Capability | In Use | Planning |
3.2.4 Public Accessibility | In Use | Planning |
<table>
<thead>
<tr>
<th>3.2.5 Cycle-friendliness</th>
<th>In Use</th>
<th>Planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3 Ensuring Design Quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.3.1 Design and urban quality</td>
<td>Erection</td>
<td>Planning</td>
</tr>
<tr>
<td>3.3.2 Art in Architecture</td>
<td>Erection</td>
<td>Planning</td>
</tr>
<tr>
<td><strong>4. Technical Quality 22.5%</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.1 Technical Execution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.1.1 Sound Insulation</td>
<td>In Use</td>
<td>Planning</td>
</tr>
<tr>
<td>4.1.2 Heat Insulation and Protection against Condensate</td>
<td>In Use</td>
<td>Planning</td>
</tr>
<tr>
<td>4.1.3 Cleaning and Maintenance</td>
<td>In Use</td>
<td>Planning</td>
</tr>
<tr>
<td>4.1.4 Dismantling, Separation and Utilization</td>
<td>Demolition</td>
<td>Planning</td>
</tr>
<tr>
<td><strong>5. Process Quality 10.0%</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.1 Management and Design</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.1.1 Project Preparation</td>
<td>Erection</td>
<td>Project Development</td>
</tr>
<tr>
<td>5.1.2 Integrated Design</td>
<td>Erection</td>
<td>Planning</td>
</tr>
<tr>
<td>5.1.3 Optimisation and Cooperation in Planning</td>
<td>Erection</td>
<td>Planning</td>
</tr>
<tr>
<td>5.1.4 Sustainability Issues in Tendering and Awarding</td>
<td>Erection</td>
<td>Tendering and Contracting</td>
</tr>
<tr>
<td>5.1.5 Requirements for optimal Utilisation and Management</td>
<td>Erection</td>
<td>Construction</td>
</tr>
<tr>
<td><strong>5.2 Building Construction</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.2.1 Building site / Building Process</td>
<td>Erection</td>
<td>Construction</td>
</tr>
<tr>
<td>5.2.2 Quality Assurance of the Building Construction</td>
<td>Erection</td>
<td>Construction</td>
</tr>
<tr>
<td>5.2.3 Controlled Commissioning</td>
<td>Erection</td>
<td>Hand over / In Use</td>
</tr>
<tr>
<td><strong>6. Location Profile 0.00%</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.1 Location Profile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.1.1 Risks at the Micro-Site</td>
<td>Overall</td>
<td>Project Development</td>
</tr>
</tbody>
</table>
6.1.2 Condition at the Micro-Site
6.1.3 Image and Character of Location and Quarter
6.1.4 Public Transport Connections
6.1.5 Proximity to Use-Specific Services
6.1.6 Supply Lines / Site development

<table>
<thead>
<tr>
<th>Criteria</th>
<th>In Use</th>
<th>Project Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1.2 Condition at the Micro-Site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.1.3 Image and Character of Location and Quarter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.1.4 Public Transport Connections</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.1.5 Proximity to Use-Specific Services</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.1.6 Supply Lines / Site development</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 19. **BNB main criteria groups, criteria groups, and criteria**

The evaluation system operates according to a hierarchical system with various levels. The levels are shown in Table 21 (own Table according to Möller and Kalusche, 2013).

The final overall assessment is shown as an overall fulfilment level once all the main criteria groups have been added together. The assessing of the sustainability of Federal buildings is carried out by auditors.

![Fig. 45. BNB certificates](BMVBS, 2011)
Certificates are awarded in respect of the building. They may bronze, silver or gold. Details of these grades are shown in Figure 45 (BMVBS, 2011). The overall fulfilment level of a Federal building should at least 65% (Anlage B1 BMUB, 2014b).

### 6.5 BNB: Process quality

A project summary is drawn up for each criterion, and the indicators are recorded in it (BMVBS, 2011). The indicators enable the sustainability of office buildings, outdoor areas, educational buildings and laboratory buildings to be assessed.

Main criteria group 5, Process quality includes criteria group 5.: Quality of Planning, and specifically criterion 5.1.1, project preparation including project development (BMVBS, 2011, p. 12).

<table>
<thead>
<tr>
<th>Sustainability criteria with the main groups of criteria, criteria group and criterion</th>
<th>Responsibility for proof</th>
<th>Phase of proof</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Process Quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.1 Management and Design</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.1.1 Project Preparation</td>
<td>Client</td>
<td>Project Development</td>
</tr>
</tbody>
</table>

*Table 20. Timing of and responsibility for verification of process quality*

The quality of the product, and of the building in particular, is significantly influenced by process quality. Efficient processes provide scope for cost reductions and quality assurance (BMUB, 2015, p. 583; Vogdt et al., 2002, p. 105). The process quality can be found in the LEED and BREEAM certification systems, but with differing percentage weightings (Amin Zeinal Hamedani and F. Huber, 2012, p. 12; Johnson, 2014).
The indicators for criteria group 5.1, Management and Design are shown in the following table.

<table>
<thead>
<tr>
<th>Level</th>
<th>Single Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Global Goal</strong></td>
<td>Sustainability Criteria</td>
</tr>
<tr>
<td><strong>Main Group Criteria</strong></td>
<td>5. Process Quality</td>
</tr>
<tr>
<td><strong>Criteria Group</strong></td>
<td>5.1 Management and Design</td>
</tr>
<tr>
<td><strong>Criterion</strong></td>
<td>5.1.1 Project Preparation</td>
</tr>
<tr>
<td>Indicator -1</td>
<td>Requirement planning or equivalent</td>
</tr>
<tr>
<td>Indicator -2</td>
<td>Sustainable Agreement on Planning Objectives</td>
</tr>
<tr>
<td>Indicator -3</td>
<td>Preparation of the Planning Competition</td>
</tr>
</tbody>
</table>

*Table. 21. Level of BNB main criteria groups*

### 6.6 Requirement planning: DIN 18205

Through its main criteria group 5, Process quality, the BNB provides a quality management for the design, construction, management and operation of buildings. Indicator -1 of criterion 5.1.1 Project Preparation based on a German industry standard (DIN). DIN 18205:1996-04 (hereinafter referred to as DIN 18205) has contained requirement planning provisions since 1996.

The DIN 18205 describes the requirement planning and includes questions about the methodical determination of the needs of all stakeholders, as the owner, the future users and the client (wikipedia, 2014b). Checklists contained in DIN 18205 are used to examine points which help to ascertain important project-related building information. Requirement planning also means that building information for subsequent planning is discussed at an earlier stage, so that quality is improved for all parties involved (Volkmann, 2008). The points that are ascertained through requirement planning are critical for further processes, since qualitative and functional aspects are defined for subsequent
planning (Gautier and Osebold, 2014). Despite this, it is not yet established as a planning discipline. Special importance is assigned to requirement planning in main criteria group 5, Process quality, where it is examined in more detail. (Hodulak and Schramm, 2011). Requirement planning is an essential and important process within the construction field as a whole. It forms the basis of the entire design and construction process of a building.

The 3 DIN 18205 checklists are shown below as examples, together with their respective headings and their main sub-divisions (Deutsche Industrienorm, 1996):

- **Checklist A: Project recording.**
  - Checklist A is used at an early stage of requirement planning. It is used for establishing very general information about the project:
    - The project.
    - Purpose of the project.
    - Scope of the project.
    - The parties involved.
    - Other groups which have an influence.

- **Checklist B: Framework conditions, goals, and resources.**
  - This examines the framework conditions, goals, and resources of principals and users. They should be recorded for the planning team that will be set up. This enables the best possible use to be made of the available resources for achieving the goals:
    - Project organisation.
    - Laws, standards and regulations.
    - Financial and time framework.
    - Project background and historical influences.
    - Influences of the land / site and the surroundings.
    - The principal's future form of organisation.
    - Details of the intended use.
    - Intended effects of the project.
• Checklist C: Framework conditions, goals, and resources.
  o Decisions regarding physical aspects of the site and building are examined. The principal's requirements in relation to the design plan are stated here. These statements should be expressed as requirements, not as the description of solutions. They should include specific statements by the principal concerning energy costs, materials and technical issues etc.
    ▪ Site and surroundings.
    ▪ The building as a whole.
    ▪ Requirements relating to the building structure.
    ▪ Room groups.
    ▪ Individual rooms.
    ▪ Fixtures, fittings and furniture.

DIN 18205 can be viewed in its entirety at www.din.de.

DIN 18205 is a translation of ISO 9699:1994 (Deutsche Industrienorm, 1996; International Standard, 1994). As it is an existing standard, requirement planning is already clearly specified in DIN and ISO. The procedural methods are defined on a national and international basis. DIN 18205 as well as ISO 9699:1994 form the basis of requirement planning. Requirement planning is consequently possible with either document. The DIN 18205 designation is retained in the following sections, but can be equated with ISO 9699. The illustrations refer to DIN and ISO.

The aim of this work was to illustrate a solution for the holistic use of the BIM methodology in sustainable construction in the public sector. Both disciplines, namely sustainable construction and the use of the BIM methodology, can be only efficient if they are started at an early stage. The following suggested approach is intended to prove this. Indicator 1 of criterion 5.1.1 Project Preparation is regarded as a significant point for drawing up a suggested approach.
Since this work concerns itself with the use of the BIM methodology in public construction sector, the principal is a state institution with a corresponding level of specialist expertise. (BMUB, 2014a). Furthermore, the principal may commission the services of requirement planners, architects, engineers, or other people with appropriate specialist skills (Deutsche Industrienorm, 1996).
7. Demonstrating the holistic approach

7.1 DIN 18205 in sustainable construction in the public sector

Within project development DIN 18205 enables roughly 70% of all BNB criteria which are required for life cycle-oriented planning among other things to be assessed. Sustainable planning goals relating to

- ecological,
- economic,
- and socio-cultural aspects, as well as
- technical quality,
- process quality

and site quality are determined. Despite the methodically ascertained DIN 18205 information and the reviewing undertaken in the BNB, no significant reduction of life cycle costs is produced in most cases (see Figure 46).

Fig. 46. Life cycle costs with conventional use
(own Illustration according to BMUB, 2014b, p. 29)
The reason for this is that all the information is only available in analogue, physical documents. This leads to information and media discontinuities between all the parties involved. The information that is methodically ascertained according to DIN 18205 is explained and outlined below.

The criterion of Project Preparation is already reviewed by an auditor during project development. In indicator -1 of this criterion, i.e. Requirement planning or equivalent (see Table 21), the basic building characteristics and requirements are defined by the user and owner through the use of DIN 18205. These characteristics and requirements form the basis of subsequent construction (BMUB, 2014a, p. 56). Based on the methodical investigation procedures in DIN 18205, numerous requirements relating to the building are explored and recorded in the project development phase. These characteristics and requirements are incorporated into indicator -2 (see Table 21). Object- and project-specific planning goals derived from indicator-1 are agreed in indicator -2 in relation to sustainability (BMUB, 2014a, p. 61). Questions are asked about these goals in the competitive tendering process (indicator -3). In addition, DIN 18205 supports the early involvement of various specialist planners, and it consequently has a positive impact on criterion 5.1.2 Integrated planning. Integrated planning helps to optimise the planning process with regard to the creation of a balanced sustainability concept. It spans the entire life cycle of a building (BMUB, 2014a, p. 62). Information derived from the methodical determining of requirements according to DIN 18205 also feeds into criterion 5.1.3 Complexity and optimisation of planning. Requirement planning lays the foundations of efficient building management. This means that operating costs can be budgeted for the use phase (BMUB, 2014a, p. 64). The sustainability requirements for the building which are derived from DIN 18205 are therefore implemented on a step-by-step basis in the outline planning process (BMUB, 2014a, p. 70). As questions about operating periods and workstation / workplace design are also included, the appropriate type of energy generation can be discussed among other issues (BMUB, 2014a, p. 72). The concept for the subsequent operation of the building is therefore drawn up as part of the requirement planning process (BMUB, 2014a, p. 80). Requirement planning is also very important in terms of the basic economic viability of the building.
(BMUB, 2014a, p. 140). As described above, requirement planning according to DIN 18205 has positive effects on the main criteria group Process quality, and specifically on criteria group 5.1 Quality of planning. The following graphic shows the influence of requirement planning in the form of DIN 18205 on criteria group 5.1. By specifying the requirements for sustainability, this also has an effect on the tendering process. (BMUB, 2014b, p. 56).

**Fig. 47. Effect of requirement planning on criteria group 5.1**

**Indicator-1: Requirement Planning according to DIN 18205 / ISO 9699**

- Sustainability-oriented object- and project-specific planning targets are agreed (Indicator-2). They can be requested during the planning competition (Indicator-3).
- Positive effect for the participation of different specialist planners. (Integrated Design).
- Balance of the sustainability concept (Optimisation and Complicity in Planning).
- Contribution to the consideration of cost-effectiveness (Sustainability Issues are specified for Tendering).
- Concept for the subsequent operation of the building (Requirements for an optimal Utilisation and Management).
Furthermore, requirement planning in the form of DIN 18205 has a positive effect on subsequent planning processes within sustainable construction in the public sector (BMUB, 2014a, p. 40,62). The following table highlights the influence of DIN 18205 on all the BNB criteria (BMUB, 2014b, p. 15,16). Criteria group 5.1 is listed again for reasons of completeness. The corresponding categories in DIN 18205 are also shown. If the corresponding categories are mentioned more than once, this is due to the many sub-items within the categories of the DIN 18205.

<table>
<thead>
<tr>
<th>Sustainability criteria with the main groups of criteria, criteria group and criteria and rating</th>
<th>relevant life cycle phase</th>
<th>Phase of proof</th>
<th>In DIN 18205 / ISO 9699 corresponding to</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ecological Quality 22.5%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2 Demand of Resources</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2.1 Primary Energy Demand not Renewable (PEnr)</td>
<td>Overall</td>
<td>Planning</td>
<td>B.2.6, B.7.5, C.2.1</td>
</tr>
<tr>
<td>1.2.2 Total Primary Demand (PEtot) and amount of PEre</td>
<td>Overall</td>
<td>Planning</td>
<td>B.2.6, B.7.5, C.2.1</td>
</tr>
<tr>
<td>1.2.3 Fresh Water Requirements and Quantity of Wastewater</td>
<td>In Use</td>
<td>Planning</td>
<td>C.3.5</td>
</tr>
<tr>
<td>1.2.4 Space Requirements</td>
<td>Erection</td>
<td>Project Development</td>
<td>B.7.3</td>
</tr>
<tr>
<td>2. Economical Quality 22.5%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1 Life Cycle Costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1.1 Building-related Life Cycle Costs</td>
<td>Overall</td>
<td>Planning</td>
<td>B.3.3</td>
</tr>
<tr>
<td>2.2 Performance</td>
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<tr>
<td>2.2.2 Stability of Value</td>
<td>In Use</td>
<td>Planning</td>
<td>C.2.1</td>
</tr>
<tr>
<td>3. Sociocultural and Functional Quality 22.5%</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>3.1 Health, Comfort and User Satisfaction</td>
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<td></td>
</tr>
<tr>
<td>3.1.1 Thermal comfort in winter</td>
<td>In Use</td>
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<td>B.2.6, B.5.3, B.7.5, C.2.1</td>
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<td>Description</td>
<td>Status</td>
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<td>3.1.2</td>
<td>Thermal comfort in summer</td>
<td>In Use</td>
<td>Planning</td>
</tr>
<tr>
<td>3.1.6</td>
<td>Influence of the User</td>
<td>In Use</td>
<td>Planning</td>
</tr>
<tr>
<td>3.1.7</td>
<td>Building-related Outdoor Qualities</td>
<td>In Use</td>
<td>Planning</td>
</tr>
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<td>3.1.8</td>
<td>Safety and Incident Risks</td>
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<td>Planning</td>
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<td>3.2</td>
<td>Functionality</td>
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<td>3.2.1</td>
<td>Barrier-free Building</td>
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<td>3.2.2</td>
<td>Space Efficiency</td>
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<td>3.2.3</td>
<td>Conversion Capability</td>
<td>In Use</td>
<td>Planning</td>
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<td>3.2.4</td>
<td>Public Accessibility</td>
<td>In Use</td>
<td>Planning</td>
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<td>3.2.5</td>
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<td>Art in Architecture</td>
<td>Erection</td>
<td>Planning</td>
</tr>
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<td>4.1</td>
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<td>4.1.2</td>
<td>Heat Insulation and Protection against Condensate</td>
<td>In Use</td>
<td>Planning</td>
</tr>
<tr>
<td>4.1.3</td>
<td>Cleaning and Maintenance</td>
<td>In Use</td>
<td>Planning</td>
</tr>
<tr>
<td>4.1.4</td>
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<td>Planning</td>
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<td>Management and Design</td>
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<td>Project Preparation</td>
<td>Erection</td>
<td>Project Development Planning</td>
</tr>
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<td>5.1.2</td>
<td>Integrated Design</td>
<td>Erection</td>
<td>Planning</td>
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<td>5.1.3</td>
<td>Optimisation and Cooperation in Planning</td>
<td>Erection</td>
<td>Planning</td>
</tr>
<tr>
<td>5.1.4</td>
<td>Sustainability Issues in Tendering and Awarding</td>
<td>Erection</td>
<td>Planning</td>
</tr>
</tbody>
</table>

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Table 22. Influence of requirement planning on the BNB criteria

The methodical determining of requirements within requirement planning based on DIN 18205 enables all the criteria shown in Table 22 to be qualitatively or quantitatively evaluated. A comparison with Table 19 again highlights the influence of DIN 18205 on the BNB criteria. Table 19 contains 46 criteria. Table 22 has a total of 32. As can be seen from Table 22, the 32 remaining criteria are life cycle-related criteria.

Questions relating to the provision of service infrastructure, as well as to planning law, urban planning, architectural, and building code aspects, are also discussed (BMUB, 2014b, p. 39). All the necessary user's and owner's quantitative and qualitative building requirements are specified. This specification forms the basis of the subsequent construction of the building. All the specifications are drawn up in collaboration with the owner and user, and in conjunction with the specialist planners that are needed and other involved parties. The whole approach promotes life cycle-oriented planning and a resulting reduction of building costs.
The client, user, owner, specialist planner or auditor is consequently able to assess a building's sustainability according to DIN 18205. The following graphic shows the influence of DIN 18205 on the in Table 22 shown BNB criteria.

**Indicator-1: Requirement Planning according to DIN 18205 / ISO 9699**

<table>
<thead>
<tr>
<th>Sustainability criteria with the main groups of criteria, criteria group and criteria and rating</th>
<th>Relevant to:</th>
<th>Relevant to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecological Quality (10%)</td>
<td>Requirement Planning</td>
<td>Overall Planning</td>
</tr>
<tr>
<td>3.1 Energy Consumption and Emission (Baseline)</td>
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<td>Economical Quality (22.5%)</td>
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<td>3.1 Building related Life Cycle Costs</td>
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<td>3.2 Stability of Value</td>
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<td>Social and Cultural Quality (22.5%)</td>
<td>Requirement Planning</td>
<td>Use Planning</td>
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<td>3.1 Health, Comfort and User Satisfaction</td>
<td>Use Planning</td>
<td>Use Planning</td>
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<td>3.2 Functionality</td>
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<td>3.3 Ensuring Design Quality</td>
<td>Use Planning</td>
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<td>Technical Quality (22.5%)</td>
<td>Requirement Planning</td>
<td>Overall Planning</td>
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<td>4.1 Technical Execution</td>
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<td>4.3 Cleaning and Maintenance</td>
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<td>4.4 Dismantling, Separation and Utilization</td>
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<td>Demolition Planning</td>
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<td>Process Quality (10%)</td>
<td>Requirement Planning</td>
<td>Use Planning</td>
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<td>5.1 Management and Design</td>
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<td>5.4 Sustainability Issues in Tendering and Contracting</td>
<td>Tendering and Contracting</td>
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<td>Location Profile (0.00%)</td>
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<td>6.1 Location Profile</td>
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<td>6.5 Vicinity to Use-Specific Services</td>
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<tr>
<td>6.6 Supply Lines / Site development</td>
<td>Use Planning</td>
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**Fig. 48. Influence of requirement planning on BNB as a whole**
Figure 49 shows the current method of gathering data. The DIN 18205 information is made available in an analogue format within physical documents. Distribution of the ascertained information from DIN 18205 into the BNB is consequently carried out manually. While the amount of information that is methodically ascertained according to DIN 18205 is very large (cf. Figures 47 and 48), the structure of the DIN 18205 information is nevertheless purely analogue. Moreover, reviewing in BNB has a positive effect on the criteria shown in Table 22. This reviewing can only be undertaken manually, as the DIN 18205 information is only provided in analogue form.

The process is consequently extremely labour-intensive, and also error-prone, due to the analogue nature of the data and the necessity for it to be reviewed manually. It is consequently affected by huge information and media discontinuities. This means that information which is essential for the entire life cycle of a building exists in an analogue, non-interoperable and non-scalable format. This results in significant losses of information between all the parties involved. This means that life cycle-oriented planning is only possible to a limited extent, if at all. Any possibility of a resulting reduction in the building costs during the design, construction and operation phases is generally ruled
out by the problems that have been described. By contrast, the interoperable and integrated use of DIN 18205 would enable critical planning decisions for the future direction of the project to be made at an earlier stage of planning. This leads to life cycle-oriented planning.

Fig. 50. Difference in costs due to life cycle-oriented planning
(own Illustration according to BMUB, 2014b, p. 29)

This life cycle-oriented planning is also promoted by the reviewing undertaken within the BNB. It is particularly in the early phases of planning that a major influence can be exerted on the quality of the building that is to be built. The positive influence on the costs of the building is greatest at the outset. Furthermore, if life cycle-oriented planning is used, the costs over the entire life cycle of a building are lower. Life cycle-oriented planning is achieved by reviewing and determining all the building requirements through the use of DIN 18205 in an interoperable, scalable and digital form. The result is a lowering of the building's life cycle costs (see Figure 50). In contrast to conventional planning, life cycle-oriented planning leads to reductions in building costs (BMUB, 2014b, p. 39). The digital and interoperable use of DIN 18205 leads to a guaranteed reduction in life cycle costs. The seamless flow of information between all the parties involved throughout the entire life cycle is also assured. Verification at an early stage, i.e. during project preparation, facilitates the cost-
neutral, qualitative correction via the BNB of all the information that has been
methodically ascertained according to DIN 18205 (PMS, 2014, p. 9). Verification takes place before the BIM methodology starts to be used. This approach makes it possible to exert a positive influence on the subsequent planning processes.

Of course, the information must be adapted to the subsequent design, and continual reviewing and correction of the facts established in the course of requirement planning based on DIN 18205 must be carried out.

In this chapter, the positive effects on the BNB criteria that can be achieved through the use of DIN 18205 have been highlighted. As can be seen, a lot of requirement planning information is methodically ascertained through the use of DIN 18205. The correct application of the described procedure is severely hampered by media discontinuities and losses of information. The following proposed approach significantly enhances and safeguards the quality of the requirement planning carried out according to DIN 18205, and of the reviewing process within the BNB. This methodical ascertaining of information also has positive effects on the BIM methodology. The positive effects are discussed in the next section.

7.2 DIN 18205 within the BIM methodology

As discussed, the use of the BIM methodology begins at an early stage (cf. Chapter 1.4). A comparison of the phases, from the preliminary design through to construction and handover of a building, makes the effect of the BIM methodology clear to the traditional compared with the digital planning process. The use of the BIM methodology enables relevant planning decisions to be taken at an earlier stage. This means that building information is required in this earlier phase too (Das and Chaudhuri, 2011, p. 23). When use is made of the BIM methodology, building information must consequently be available earlier. This is essential in order to enable the relevant planning decisions to be made. This shift is shown in the following graphic. This makes it clear that the use of the BIM methodology causes an increased effort at an early stage. The
increased effort is measured and shown in relation to the planning decisions, as compared to traditional planning without using the BIM methodology. Furthermore, the diagram presents that the greatest influence on the building characteristics can be exerted at the beginning.

![Fig. 51. The MacLeamy curve](own Illustration according to AIA, 2007, p. 21)

Shifting planning decisions forward to an early phase reduces the costs of design changes in the construction process. The earlier the planning decisions are taken, the more the costs can be positive influenced. This increases planning certainty. In the later stages, influencing the quality of the building requires considerable effort. The more changes that are made in the later stages, the higher the costs of the building become. Cost increases due to late changes have a negative impact on time schedules and quality. Therefore the use of the BIM methodology generally has positive consequences, since relevant decisions are made at an early stage. The decisions made have a major influence on the quality of the final building (AIA, 2007; Azhar, 2011; Eastman et al., 2011; Liebich et al., 2011; Light, 2011). What's more, the methodical ascertaining of information according to DIN 18205 now occurs as part of requirement planning. In particular, the early, methodical ascertaining of information during project development occurs exclusively through the use of
requirement planning. This has a positive influence on the subsequent planning process, and it occurs due to the involvement of all the stakeholders, such as the client and the user (BMUB, 2014a). Requirement planning consequently produces synergies in the use of the BIM methodology. The use of the BIM methodology is secured through the early, methodical ascertaining of information. Planning decisions are shifted forward to an earlier phase. The early setting of requirements based on DIN 18205 means that clear project goals are defined and quality is consequently improved (NBBW, 2014). The early collating of the information required for relevant planning decisions increases the value created in the subsequent phases (May, 2014). Information is clearly defined. This allows changes to be decided on in a phase when their influence on the building characteristics is at its greatest. This influence is also achieved at a lower financial cost. The reviewing and evaluation of requirement planning through use of the BNB means that quality, costs and time schedules, as well as all the other DIN 18205 requirements, are already reviewed and evaluated in relation to criterion 5.1.1 Project preparation. This evaluation ensuring the building information that is to be used in BIM. However, as described in Section 7.1, requirement planning is carried out using analogue physical documents. This means that integrated use of the information throughout the work stages is not possible. Losses of information arise as a result of numerous information and media discontinuities. These observations lie behind the academic approach outlined in this work. The implementation and digital integration of requirement planning on the basis of the DIN 18205 in a new XML schema preserves the whole design, construction and operation process. This new XML schema can consequently be used during project development as a dedicated phase for gathering building information in relation to both sustainability and the BIM methodology (see Figure 52). The quality of the whole digital planning process is improved. The implementation and integration of DIN 18205 in a new XML schema enables the methodically ascertained outcomes to be used as a building information container throughout the entire life cycle. Implementation of requirement planning and its digital integration into the new XML schema consequently ensure the entire process of design, constructing and operating a building. This creates a new, holistic connection between sustainability in public construction sector and the
BIM methodology. A huge amount of planning decisions can therefore be made during the project development phase. The planning decisions and the changes associated with them have less impact on costs than those made during later phases.

Fig. 52. Planning decisions in the course of requirement planning (own Illustration according to BMUB, 2014a, p. 39).

7.3 Implementation of DIN 18205 in the new XML schema

XML (extensible markup language) is chosen as an appropriate method of mapping DIN 18205 and defining a container template. The XML Schema Definition (XSD) is used as the method of describing the template. In short, it satisfies the following requirements:

- interoperability,
- extensibility,
- scalability
- human- and machine-readable,
- conforms to a specified standard,
- has a unique definition.
In general terms, an XML schema defines elements and attributes which may be present in an XML document. The XML Schema consequently serves as a template for an XML document (Amrhein, 2015). Both an XML schema and an XML document are described in the XML language. The use of the XML language enables structures to be defined via an inheritance hierarchy (Mochol and Schild, 2007). The semantics approved by the World Wide Web Consortium are used to describe them (W3C, 2015). The XML language consequently fulfils the aforementioned requirements in the following respects (Harold, 1999; Skulschus et al., 2011):

- XML is used for the platform- and implementation-independent exchanging of digital information.
- XML is an extensible markup language.
- XML is written in ASCII (American Standard Code for Information Interchange) and is therefore human- and machine-readable.
- XML follows a fixed inheritance hierarchy.
- XML has a unique World Wide Web Consortium (W3C) definition and it consequently constitutes a standard.
Fig. 54. Definition of the model

DIN 18205 is consequently mapped in this work as an XML schema. The container derived from the XML schema can be used both for evaluating sustainability and for the accompanying efficient editing of the building information model. This results in a holistic approach to the use of the BIM methodology in sustainable public construction sector. The XML schema and the digital interoperability that has been described enable the information to be accessed by all the parties involved in planning, throughout both the planning process and the life cycle as a whole. DIN 18205, as an XML schema, is consequently defined according to a uniform, worldwide standard with no licence fee (W3C, 2015). Like DIN and ISO, this description of a DIN 18205 container can be understood and used on a worldwide basis. As the proposed approach is intended to be used internationally, ISO 9699:1994 is shown as the XML schema in Appendix A and B. Altova's XMLSpy program is used to produce the XML schema.
7.4 The XML schema as the DIN 18205 container

The XML schema is used to define the quantities of information that are expected, and it allows that information to be shown in a structured manner. In addition, the quantities of information are assigned to a value range, so that the information types are firmly defined. This definition enables the XML document generated by the XML schema to be saved on a platform- and implementation-independent basis.

Once it has been completed, the XML schema consequently contains the definition of all the information that is expected. The schema can then be converted into an XML document, for example by using the software that has been mentioned. Unlike the XML schema, the XML document contains reliable, quantitative and qualitative building information.

The following graphic shows the container in diagrammatic form as well as the XML schema within it.
Due to its size, the entire new XML schema of the ISO 9699 is shown in Appendix A. The XML schema documentation can be found in Appendix B. The structure of the schema is explained by means of this schema documentation. The XML schema has been validated according to the current W3C rules, and it is valid.

### 7.5 Use of the container: DIN 18205

In order to highlight the added value of the container, there follows an overview of the specific ways in which it can be used. As highlighted in the previous sections, DIN 18205 is mapped as a template in the form of a new XML schema. This schema acts as a container for the DIN 18205 data structure. The XML document can be generated from this template. This is done by using the export function of the stated software. The XML document is now the DIN 18205 container. The XML document is designated below as BI-18205 (building information 18205).
Numerous items of data are needed in order to fill the BI-18205. These come from external systems in which a calculation or methodical determining process has been carried out. The BI-18205 is filled via an automated interface. The development of this interface and other interfaces that are referred to does not form part of this thesis.

The following graphic shows in diagrammatic form the opening of the BI-18205 in a spreadsheet.
To do this 1) The container: DIN 18205 template (XML schema) is added to a spreadsheet program and 2) the XML schema elements are assigned to the cells in the spreadsheet. 3) the BI-18205 derived from the schema will be imported. The information contained in, is visualised in the spreadsheet. Information can now either be added, visualised or modified. Then 4) the
information is transferred back to the BI-18205. The BI-18205 still has the container information in it: Model of DIN 18205 (XML schema). This procedure can be carried out in any phase of the project. This allows the methodically determined or calculated information of the requirement planning to be validated, modified, or displayed as the project progresses.

As described, the data contained in the BI-18205 is required for the BNB sustainability assessment (see Figures 47 and 48). BI-18205 data is transferred into the BNB assessment matrix via an automated interface. The BNB allows an assessment of sustainability. Through this assessment, in the project development the BI 18205 is already validated and reviewed in their sustainability. If the level of sustainability is not adequate (cf. Figure 45), the BI-18205 can be improved (see Figure 59). This process can be repeated as often as necessary. This procedure takes place in project development. Before the preliminary design or the design starts in the actual work stages, the container: Model of DIN 18205 (XML schema) and the resulting BI-18205 already provides sustainable building information (see Figure 60). If BIM now begins, the persons involved can use the BI-18205, and they can consequently define a sustainable building information model on a step-by-step basis.
Almost 70% of the methodically determined information will be sustainable assessed.

Fig. 60. BI-18205 validation within BNB

The BI-18205 can now be refined using the results of the geometric knowledge out of the BIM. All the data in the BI-18205 is based on alphanumeric information. The initial virtual verification of it is carried out when a building information model is defined. As BIM progresses, the required data can be retrieved and rewritten into the BI-18205 if improvements are made. The rewritten information can equally be assessed from the standpoint of sustainability within the assessment matrix. The BI-18205 provides a direct two-way link between the BIM methodology and sustainability. As BIM progresses, this digital nD building information model also enables the data to
be verified using additional calculation programs. It can if necessary be rewritten into the BI-18205.

Fig. 61. Use of BI-18205 in the BIM methodology
7.6 Holistic result of the container: Model of DIN 18205

As described, requirement planning is undertaken through the reviewing and determining of all the building requirements based on the use of BI 18205 in conjunction with all the parties involved. The DIN 18205 container allows the digital, methodical ascertaining of information and the integrated assessing of sustainability according to the BNB. This enables improved life cycle-oriented planning to be achieved. The result is a reducing of the building’s life cycle costs. The new DIN 18205 container that has now been created and the resulting BI-18205 enables requirement planning to be carried out digitally based on DIN 18205 during project development. Moreover, the assessing of sustainability according to the BNB involves the reviewing of roughly 70% of the information that is methodically ascertained according to DIN 18205. This produces huge increases in quality. Requirement planning is now viewed as a dedicated phase in its own right. The digital and interoperable BI 18205 is reviewed via the BNB. This further improves the quality of life cycle-oriented planning. The improvement is shown in figure 62.

![Fig. 62. Life cycle costs using BI-18205](own Illustration according to BMUB, 2014b, p. 29)
Media discontinuities within requirement planning are significantly reduced through use of the BI-18205, and the degree of integration of the planning process is increased. The proposed approach that has been devised produces a difference in costs between conventional and life cycle-oriented planning. This increases the quality of the building information for the design, construction and operation process. Quality, costs and time schedules are ensured. Figure 62 shows this change in the form of the cost reductions brought about by life cycle-oriented planning. A dedicated requirement planning phase brings forward the point in time where the curve representing costs for life cycle-oriented planning intersects the curve representing the extent to which costs can be influenced. This prolongs the period during which planning can be influenced in order to reduce costs through the use of a life cycle-oriented approach. This longer period provides more planning possibilities. Greater influence can consequently be exerted on costs, and the difference in costs compared to conventional planning is greater (compare difference marked as 1 in Figure 62 with Figure 50). The assessing of the BI-18205 sustainability through the use of BNB as well as the implementation and digital integration of DIN 18205 in a new XML schema enables the editing of the building information model to be started at a high level (see Figure 63).

Fig. 63. The bringing forward of the BIM methodology with BI-18205
(own illustration according to AIA, 2007, p. 21)
The moving of the planning decisions shown in Figure 51 is brought forward to an even earlier phase by the BI-18205. This is possible because the requirement planning information is available in a digital, structured format within the BI-18205. The building information which is geometrically mapped at this time is shown in unambiguous, digital form within the BI-18205. The required building information exists within the BI-18205 at the start of digital planning. Moreover 70% of the building information has been reviewed from a sustainability perspective (see Figure 60).

The aim of the work has been to design, produce and present a method for applying the BIM methodology in public construction sector in a way which takes account of sustainability aspects. This has been achieved through the digital integration of DIN 18205 and its implementation in a new XML schema. As shown in Figure 63, the BIM methodology can begin with a greater density of information. The provision of building information within the BI-18205 brings the planning decisions forward to the project development phase. The DIN 18205 information is available throughout the entire life cycle. Planning decisions in relation to the building are more cost-neutral. The following graphic shows the curve produced by Baier.

![Fig. 64. Holistic result obtained through the use of BI-18205](image-url)
The BI-18205 provides interoperable, extensible, scalable sustainability information according to a specified standard, as well as clearly defined and sustainable building information. This brings planning decisions forward to a more cost-neutral phase. BI-18205 is available as a validation tool throughout the design process and also the operation phase. The BI-18205 ensures the provision of the building information required for the holistic use of the BIM methodology in sustainable construction in the public sector.

The outcome is the container: Model of DIN 18205 and the resulting BI-18205. The definition and development of the new XML schema in line with the requirements of the DIN 18205 means that requirement planning can now be used as a dedicated phase in its own right. The XML schema that is implemented acts as a container for the model of DIN 18205. This model presents all the requirement planning information in a structured, digital format. The BI-18205 makes it possible evaluate and review the information that is needed for the integrated application of the BIM methodology. This leads to improved life cycle-oriented planning and more efficient use of the BIM methodology.
8. Overall conclusions and outlook

8.1 Issues examined and aim of this work

The aim of the work has been to design, produce and present a method for applying the BIM methodology in public construction sector in a way which takes account of sustainability aspects. The individual chapters of this thesis have been used to examine a connection between the BIM methodology and sustainability within public construction sector. The individual investigations have shown that approaches are available, but there is no predominant, fundamental connection.

The following topics have been examined in this regard:

- Definition of the term 'BIM' including all possible aspects of it, and its delimitation from other digital working methods.

- Worldwide application of the BIM methodology in public construction sector.

- The models that exist around the world for assessing the BIM maturity in a company or a project.

- The interoperable IFC interface that is used on a worldwide basis, including in public construction sector.

- Sustainability in construction, and in particular process quality of the BNB, a sustainability certification system for public construction sector.

Based on these analyses, a holistic approach has been outlined which takes account of sustainability as defined by the BNB and the use of the BIM methodology in public construction sector. The implementation and digital integration of DIN 18205 in a new XML schema ensures the whole design,
construction and operation process of a building. The new XML schema enables the information that is methodically ascertained according to DIN 18205 to be digitally reviewed according to the BNB. Life cycle-optimised planning is the result of this review. In addition, use of the BIM methodology is facilitated. Planning decisions can be taken at an earlier stage and the provision of the information required for use of the BIM methodology is ensured. Cost savings are consequently made throughout the building’s entire life cycle (see Figure 62) and during use of the BIM methodology (see Figure 64). Further potential savings result from the process of change due to the implementation and the digital integration of DIN 18205 in a new XML Schema. For the first time, the methodically ascertained information is made available in a digital, interoperable form during design, but also during subsequent work stages. Information and media discontinuities have been eliminated. This means that information only has to be ascertained once, and not repeatedly for each phase. This results in savings in each individual phase of the design, construction and operation process, starting with the costs of the BNB auditor who uses the BI-18205 information.

Fig. 65. Building information provided by BI-18205
8.2 Summary of the results

In the construction sector for about the last 20 years building information modelling has been a methodology which is synonymous with holistic processes and working methods in relation to digital design, building and operation. The term was already used with roughly the same meaning in 1970. In the 1970s terms such as Building Product Models or Product Information Models were used to describe the concept, technology and methods involved in relation to all the phases of the construction of a building.

The BIM methodology combines many different services – costs calculation, life cycle management, sustainability studies, and energy efficiency calculations to name just a few examples. However, depending on people's levels of professional focus and skills there are widely differing viewpoints as well as differences in performance requirements relating to the degree of integration of the building information model and the scope of services that it encompasses. There are differences in user potential, issues and processes. The precondition for error-free, efficient integration is the establishing of a consistent operational framework for the application of the BIM methodology.

Investigation of the use of the BIM methodology in public construction sector has shown that its use is made mandatory in some countries by corresponding standards and guidelines. In all countries where the use of the BIM methodology is mandatory, the basis for this requirement is created exclusively by a state institution. Such institutions are generally involved in public construction sector, and they manage a large number of buildings. There are some project constraints, such as a project's spatial dimensions or costs, which expulse mandatory application. However, it should be noted that a cooperation with these institutions is only possible if the BIM methodology is used on companys side. The thinking behind this mandatory requirement is to improve the efficiency of the planning, construction and operational processes. This is necessary due to the large number of buildings that have to be managed. The BIM methodology is used as a medium for the efficient and high-quality management of these buildings. Consideration of existing bodies of rules
makes it clear that they are not complicated technical descriptions, rather they form the basis of a common language for undertaking the projects using the BIM methodology. The body of rules acts as type of functional specification for the contractor and the state institution, and it consequently facilitates communication within the project. Semantic conventions enable and facilitate working with complex BIM software. This approach is supported by standards which have been specifically developed for the BIM methodology. These standards include ISO standards which form the basis of joint use and which provide further information about the existing bodies of rules. Close collaboration can be noted in all countries where buildingSMART is available.

The approach of introducing the BIM methodology in the public construction sector on a mandatory basis which is used in Great Britain is accompanied by the simultaneous introduction of industry standards. The introduction of mandatory BIM methodology in the public construction sector is illustrated by a maturity model, the 'evolutionary BIM ramp'. In parallel with this, the development of necessary industry standards is specified based on clear requirements which apply to BIM. The ultimate aim in Great Britain is to achieve a new standard of interoperability. However, rather than being used for assessing the maturity level within an institution or a project, the maturity model in Great Britain is a roadmap showing the direction of travel involved in the development of an integrated building information model which provides added value for all the parties involved throughout a building's life cycle and enables them to use the building information model consistently. The other BIM maturity models that have been described enable maturity level to be determined. The prerequisite for this is a basic knowledge of BIM. This can lead to complications in the case of self-assessments since certain questions may be answered incorrectly, or not at all, due to a lack of knowledge. The TNO model is unique in this regard. In the case of the TNO QuickScans, an auditor is responsible for ensuring that the right questions are asked. He can also provide assistance with the questions so that they elicit correct and precise answers. The other maturity models presented nevertheless remain valid for use. They enable the BIM maturity to be determined, and this helps when selecting a company. They allow an opinion to be formed regarding a company's proficiency in using the
BIM methodology. The level of experience of using BIM within a project is specified as well.

The basis for use of BIM and the corresponding methodology is interoperability. The structure of buildingSMART and the high level of commitment of its chapters in many countries promotes the autonomous development of the IFC interface. The application offers great advantages, particularly for the public construction sector in conjunction with the BIM methodology. The interface represents the only operational, non-proprietary standard in the world for exchanging digital information in the construction field. In addition, this interface enables not only geometric information to be exchanged, it also makes possible the error-free transfer between the parties involved in a project of other important parameters for a building. It is possible to make object-oriented information and other digital descriptions available on an interoperable basis throughout the entire life cycle. These are the crucial advantages compared to a proprietary interface. The technology for this exchange is provided by the IFC interface. The refinement of the ISO standard led to IFC being presented in 1997 as the first non-proprietary interface in the construction field. Since then it has been continuously enhanced and adapted to the requirements of the construction sector. The switch to the platform concept using MVD enables it to be used in a monitored, easily understood way for various domains in the construction field. The semantics of the interface are provided by the IFD. The IFDs provide object-oriented, product-related information in various languages, and they consequently ensure that the exchanged information can be used on an international basis. All the components that have been mentioned, such as IFC, MVD and IFD, are based on the ISO standards, which accordingly guarantee correct implementation throughout the world. IFC version 4.0 also enables sustainability information to be exchanged via the interface for the first time.

Consideration of the earth’s resources from the sustainability perspective has come to the fore over recent decades due to increasing awareness of specific issues. As a major consumer of these natural resources, construction has a major stake in the guaranteeing of a sustainable future through the sensible
use of finite resources. Owing to this focus on sustainability, sustainability evaluation systems have emerged in the construction sector in parallel with the prevailing global sustainability strategy. As a rule, the building is evaluated based on aspects relating to sustainability right from the project phase through to and including change of use or demolition. There are a variety of systems for doing this which can be used on a national or international basis. Each system has a specific field of application, depending on where it is used. This is dependent on where the respective state's focus lies in terms of the evaluation of sustainability. Consideration of the history of these systems and a comparison of the content of the assessment topics reveals that there are parallels between the content of the largest systems. These parallels also relate to their ability to be used internationally. Following on from these conclusions, the BNB sustainability certification system was examined in more detail. It was established that the process quality main criteria group, in particular the project preparation criterion, provides an especially high level of added value in relation to the assessing of sustainability, and also in relation to the use of the BIM methodology in public construction sector. This led to a solution being proposed for combining the BIM methodology in public construction sector with sustainability in an interoperable, digital manner.

The sustainability is reviewed as part of the project preparation criterion in requirement planning. Requirement planning can be used as a form of quality management for the planning process as well as the subsequent processes. As the existing requirement planning standard is already clearly specified in DIN and ISO, the procedural methods in public construction sector are specified on a national and international basis. Furthermore, requirement planning has a positive influence on many processes that are involved in the BIM methodology as well as many which relate to the BNB sustainability evaluation. Undertaking the requirement planning process on a digital basis provides opportunities for reciprocal improvements in efficiency and quality. Due to the synergies that are provided through the use of the BIM methodology and in relation to sustainability, it was chosen to implement and integrate the DIN 18205 in a new XML schema.
8.3 Academic and practical significance of the container

The presentation of requirement planning as a container: Model of DIN 18205 as an XML schema forms the basis of an interoperable, digital solution. The XML schema describes the requirements relating to the needed information as well as its content. These are stated and clearly defined in the schema. Both the type of information and the values range are clearly delineated. The digital mapping of the requirement planning processes as a container in a new XML schema provides a clear description of how to obtain the required information. This clarity of description is made possible by the XML language. As IFC, XML is defined on a uniform, worldwide basis through W3C. The standard can be viewed without charge and is consequently available to everyone. In addition, ASCII is a text-based encoding system which is human- and machine-readable. It applies to both the XML schema and the XML document. The XML schema is used to define a template file for an XML document: the BI-18205. During requirement planning the information is consequently stored in BI-18205 so that it can be made available to the parties involved on a digital, interoperable basis as the project progresses. This can be done using manufacturer-specific programs such as spreadsheet programs, but it can also be provided as part of the digital planning process. The information can also be used when undertaking reviews. When doing this, results form geometric information can be compared with the information from BI-18205. In all phases of the project the BIM methodology makes it possible to validate the building information from BI-18205 against the information relating to the building under construction. It also makes sense to use BI-18205 in the BNB both within and outside the process quality main criteria group. This information can also be used to evaluate criteria from other main criteria groups during the project preparation phase. Any changing of the plans that may be required is therefore moved to a phase which is not in any way time-critical. In addition, boundary conditions which are not generally clarified until the design phase are discussed at a very early stage due to requirement planning BI-18205, and are disclosed to all the parties involved.
This work is a representation of the status quo concerning the application of the BIM methodology in public construction sector. Moreover, a review is undertaken of its usability within sustainable construction. This leads to a worldwide overview of the sustainability certification systems in the construction field, and of the use of the BIM methodology in public construction sector. These two worlds are brought together as proposed in BI-18205. This is possible due to the use of identical, precisely defined information. This information can be used both in the sustainability field and within the BIM methodology. In addition, the information can be represented and updated using digital, interoperable methods. The existing DIN and ISO standard enables these methods to be used on a worldwide basis.

8.4 Further research

The onward march of globalisation which also affects construction makes it necessary to rethink methods of working. Observation of the sustainability certification systems used around the world shows that they have features in common. One reason for this is no doubt the global sustainability strategy and the objectives of the sustainability certification systems in the construction field which the various countries have derived from it. A detailed investigation must be undertaken into the extent to which requirement planning relating to Indicator -1 is transferrable from the BNB into the process quality of other sustainability certification systems.

Use of the BIM methodology is also viewed by the manufacturers of the BIM systems in global terms. When these programs are sold, nothing is changed apart from the language and the user interface. buildingSMART recognised this global creation of value at a very early stage, and it promotes worldwide participation in, and an international view of, the BIM methodology through its business model. The global, uniform application of the BIM methodology requires industry standards. Moreover, they are required both at a national and international level. Without a common standard, whether it is has a national or international foundation, the productive, successful use of the BIM methodology is hard to achieve.
In order to a successful introduction of the BIM methodology, changes also need to be made to construction contracts for services that are to be provided using the BIM methodology. There is no doubt that the motivation behind the use of the BIM methodology is financial in nature. This motivation is perfectly understandable in a market economy. Changes to contracts and the development of standards relating to the use of the BIM methodology are an essential process within the introduction of the BIM methodology.

The use of common standards, such as BI-18205 which has been developed in this field, enables building information to be used without barriers. The information within BIM can consequently be used in public construction sector on a multi-disciplinary basis. This provides great potential in terms of object orientation and the use of BIM across the whole life cycle. Integrated use of the building information model is made possible by the addition of relevant information in the form of a additional dimension (e.g. cost, schedule, etc). Uniform rules in the form of bodies of rules or standards would allow automated accessing of information, which in particular simplifies processing tasks in the public sector construction field, e.g. the administration of large areas of buildings.

The development of contractual specifications and new uniform standards are key elements in extending interoperability. Interoperability is a core component of the BIM methodology in public construction sector. The continuous enhancement of the IFC interface for exchanging the necessary digital information out of BIM is inevitable, and influence the development of the new standards and guidelines. Increasingly exacting requirements make a properly working, non-proprietary interface ever more important in relation to the specialist disciplines which are responsible for the technical building components.

More detailed reviewing of the existing workflows that are used is necessary in the countries where BIM application is mandatory. This investigation will enable conclusions to be drawn regarding the aspects referred to here, and it will
consequently enable global development of the BIM methodology in public construction sector to take place in parallel with sustainability.
9. Glossary

British Standards Institution: Multinational service provider whose main activity is the drawing up of standards and the provision of standards-related services.

buildingSMART Data Dictionary: The buildingSMART Data Dictionary (bSDD) makes it possible to compile multilingual dictionaries or ontologies. It is a reference library which has the task of supporting collaboration across the construction industry. The bSDD is one of the main components of the buildingSMART program for data standards. In 2008 IFD was incorporated into buildingSMART International, and it is now therefore called bSDD.

Brundtland / Brundtland report: Norway's environment minister between 1974 and 1979. Chaired the United Nations World Commission on Environment and Development (otherwise known as the Brundtland Commission) As the chairperson, she was responsible for the Brundtland Report.

Cooperative Research Centre for Construction Innovation: the Cooperative Research Centre is an Australian government programme that was set up in 1990 for promoting key areas of Australian research (manufacturing technology, information and communication technology, mining and energy, agriculture and rural-based manufacturing, environment and medical science and technology). CRC for Construction Innovation is a research centre which includes manufacturing technology in its remit.

CIMsteel Integration Standards (CIS/2): a product model for the electronic exchanging of information relating to structural steel projects.

Building Construction Authority (BCA): the BCA is an agency that forms part of the Ministry of National Development. It is responsible for the development of a pleasant built environment in Singapore. BCA is responsible for buildings, structures and infrastructure which are provided for community use.
Constructing Excellence: is a construction industry membership organisation which is based in Great Britain. The organisation's membership is drawn from across the entire construction sector – from contractors and consultants to suppliers, including suppliers and manufacturers of construction materials and structural components. Founded in 2003, Constructing Excellence drives forward the proposals of the 1994 Latham report and the 1998 Egan report.

Uniclass: Uniclass is a classification system for the construction industry. It is intended to be used for organising library materials and structuring product literature and project information. It includes CAWS (Common Arrangement of Work Sections for building works) and EPIC (Electronic Product Information Co-operation).

Capex & Opex: Investment expenditure is termed Capex (capital expenditure). Its counterpart is operational business expenditure or 'Opex'. Together, Capex and Opex make up Totex (Total expenditure). The British government hopes to achieve 20% efficiency savings through the correct use of BIM.

CPIC: Construction Project Information Committee. Responsible for providing best practice guidelines and their content and form. Also responsible for the preparation of product information (construction production information). Its members are: The Royal Institute of British Architects (RIBA), The Royal Institute of Chartered Surveyors (RICS), The Institution of Civil Engineers (ICE), Chartered Institute of Architectural Technologists (CIAT), The Chartered Institution of Building Services Engineers (CIBSE), The Chartered Institute of Building (CIOB), The UK Contractors Group (UKCG), and The Landscape Institute (LI).

Digital Plan of Work in the BIM Toolkit (dPoW): The Digital Plan of Work is a free tool specifically designed to enable the project leader to clearly define the team, responsibilities and an information delivery plan for each stage of a project – who, what and when – in terms of documents, geometry and property-sets. For the first time, the Digital Plan of Work will unify data and product descriptions (CAD User, 2015).
Governmental Soft Landings (GSL): The aim of the British government is to achieve better results during planning and construction. Governmental Soft Landings (GSL) is a government initiative in support of this aim. This goal is to be achieved through the use of BIM. The use of BIM is intended to secure the rate of return that can be achieved in the operational phase.

IDM: Information Delivery Manual. IDM is a key management tool within collaboration between different parties involved in a construction project. It specifies project-specific definitions (e.g. size of texts) as well as information (e.g. who supplies what to whom?). An IDM consequently facilitates management of the process organisation. Its content is agreed by all the parties involved. This means that the IDM resolves both technical issues and those relating to content.

ICT: information and communication technology

IFC: the Industry Foundation Classes (IFC) are an open standard in the construction field for the digital description of building models (Building Information Modelling). The IFCs are defined by buildingSMART International (bSI), formerly the Industry Alliance for Interoperability (IAI). The IFCs are registered under ISO 16739.


LandXML: Is a file format for exchanging information on geo-referenced objects. It is an XML application and allows the sending of objects with attributes, relations and geometries, particularly for surveying and sub-surface construction applications.

MasterSpec: MasterSpec is the leading company for writing technical specifications for the construction industry. The specifications are used by architects, engineers and landscape architects among others. MasterSpec is
published by Architectural Computer Services (ARCOM) for the American Institute of Architects (AIA).

NATSPEC: Founded in 1975. A not-for-profit organisation made up of professional bodies and government-owned bodies in the design, build and construct field as well as the property industry.

STEP (STandard for the Exchange of Product model data) is a standard for describing product information. It specifies functional as well as physical aspects of products. It is structured according to ISO standard 10303. The standardisation that it provides allows information to be exchanged between different systems. Product information can be depicted for the entire life cycle. ISO 10303 is subdivided into several APs (Application Protocols). Each AP has its own field of use.

Senate Properties: up to 1995 the Finnish state body was administered by the National Board of Public Building. In 1995 this was abolished and divided up as a state-owned body between 15 real estate firms. The largest of them was the State Real Property Agency (SRPA). In 1999 SRPA became a government-owned company, and in 2001 it was renamed Senate Properties.

StLB: standard specifications book comprising various collated tender wordings for construction services that have been put together by the German Joint Committee for Electronics in Construction (GAEB).

XML: Extensible Markup Language. Denotes an extensible markup language. XML is a format for presenting hierarchically structured information in the form of text files. It is used for exchanging platform- and implementation-independent digital information between computer systems.
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Appendix A

Briefing_Checklists

Briefing_checklist_A

Annex A represents a preliminary stage in the preparation of the brief and is intended to establish a very general outline of the type of project and those people likely to participate.

Briefing_checklist_B

By concentrating on the context, aims and resources of the client and users, annex B should provide an understanding for the design team which will result in collective decisions which make full use of the available resources to achieve the aims within the context. The data should not be expressed in terms of design requirements. Annex C is reserved for such information.

Briefing_checklist_C

This annex transforms the content of the previous annexes into individual design decisions on the physical aspects of the site and building(s). Decisions in annex C should not be confused with the design process as they are made individually and in isolation, whereas the subsequent process of designing involves the understanding of the totality simultaneously with its parts and forms the latter into an indivisible whole. These individual decisions may be left to the designer, but even the inexperienced client may have ideas about the design means of meeting his requirements. As far as possible, the decisions in annex C should be stated in performance terms. The decisions should take account of relevant matters such as cost of energy and materials, technical and organizational matters, site constraints, forms of construction, and the adaptability and durability of the design.
Annex A represents a preliminary stage in the preparation of the brief and is intended to establish a very general outline of the type of project and those people likely to participate.

By concentrating on the context, aims and resources of the client and users, annex B should provide an understanding for the design team which will result in collective decisions which make full use of the available resources to achieve the aims within the context. The data should not be expressed in terms of design requirements. Annex C is reserved for such information.

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These general Statements will be expanded in sections B.4 and B.6.

A.2.3 Tasks of the brief

This International Standard applies to all kinds and sizes of design project. It can also apply whatever the chosen function or purpose of the brief, for example instructing, promoting discussion, recording, as a basis for evaluation or in a formal competition to select consultants. It can be used by all those taking part in the preparation of the brief, for example clients, consultants, users and any others who are authoritative, informed or likely to be affected. However, it has particular relevance for the client who, as initiator and purchaser of the works, will retain the responsibility for the project and its general management, including the choice of a designer, the preparation of the brief and the evaluation of any response to it.

A.4.1 Client

In order to facilitate initial contacts, names, addresses, telephone numbers, telex and facsimile (fax) numbers should be provided for all organizations and individuals likely to participate in the project. The name of any official representative of an organization should also be given here. Further detailed information is provided in B.1.
In order to facilitate initial contacts, names, addresses, telephone numbers, telex and facsimile (fax) numbers should be provided for all organizations and individuals likely to participate in the project. The name of any official representative of an organization should also be given here. Further detailed information is provided in B.1.

In addition to the participants and those paid by the client to carry out the project, there will be related groups concerned with some aspects of the project. It is important that the participants should have information about the roles and organization of such bodies.

A.5.1 Central government

A.5.2 National and international bodies

A.5.3 Local government

A.5.4 Town planning and building control

A.5.5 Financiers

A.5.6 Groups or persons with special knowledge or interest

A.5.7 Site owners or tenants

A.5.8 Neighbours and their consultants

A.5.9 Media

A.5.10 Insurers
Appendix B

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Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

Appendix B

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### A2.2 Main aims of the project

These general Statements will be expanded in sections B.4 and B.6.

### A2.3 Tasks of the brief

It can be used from the time when the client first considers the possible need for a building project. It should be of value when the client and others are attempting, in consultation with any necessary consultants, to document their needs, aims, resources and the context of the project, and any other problems arising, in the form of a "brief".

This International Standard applies to all kinds and sizes of design project. It can also apply whatever the chosen function or purpose of the brief, for example instructing, promoting discussion, recording, as a basis for evaluation or in a formal competition to select consultants.

It can be used by all those taking part in the preparation of the brief, for example clients, consultants, users and any others who are authoritative, informed or likely to be affected. However, it has particular relevance for the client who, as initiator and purchaser of the works,
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    <xs:documentation>These general Statements will be expanded in sections B.4 and B.6</xs:documentation>
  </xs:annotation>
</xs:element>

element A2/A.2.2_Main_aims_of_the_project

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## A2/A.2.3_Tasks_of_the_brief

| Source | <xs:element name="A.2.3_Tasks_of_the_brief" type="xs:string">
|        | <xs:annotation>
|        |  <xs:documentation>It can be used from the time when the client first considers the possible need for a building project. It should be of value when the client and others are attempting, in consultation with any necessary consultants, to document their needs, aims, resources- and the context of the project, and any other problems arising, in the form of a “brief”.
|        |  
|        |  This International Standard applies to all kinds and sizes of design project. It can also apply whatever the chosen function or purpose of the brief, for example instructing, promoting discussion, recording, as a basis for evaluation or in a formal competition to select consultants.
|        |  
|        |  It can be used by all those taking part in the preparation of the brief, for example clients, consultants, users and any others who are authoritative, informed or likely to be affected. However, it has particular relevance for the client who, as initiator and purchaser of the works, will retain the responsibility for the project and its general management, including the choice of a designer, the preparation of the brief and the evaluation of any response to it.</xs:documentation>
|        | </xs:annotation>
|        | </xs:element>
Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

Appendix B

complexType A3

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  </xs:annotation>
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    <xs:element name="A.3.2_Quality" type="xs:string"/>
    <xs:element name="A.3.3_Financial_frame" type="xs:string"/>
    <xs:element name="A.3.4_Timeframe" type="xs:string"/>
    <xs:element name="A.3.5_Current_stage_of_project_planning" type="xs:string"/>
    <xs:element name="A.3.6_Future_changes" type="xs:string"/>
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</xs:complexType>
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element A3/A.3.1_Size

```
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element A3/A.3.2_Quality

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element A3/A.3.6_Future_changes

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Appendix B

complexType A4

diagram

children
A.4.1_Client A.4.2_Occupiers_and_users A.4.3_General_manager_or_administrator A.4.4_Briefing_consultants A.4.5_Designer A.4.6_Other_consultants A.4.7_Builder

used by
Briefing_checklist_A A.4_Identity_of_participants

annotation
documentation
Identity of participants

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    <xs:element name="A.4.2_Occupiers_and_users" type="Adress_information_A"/>
    <xs:element name="A.4.3_General_manager_or_administrator" type="Adress_information_A"/>
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</xs:complexType>
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Appendix B

element A4/A.4.1_Client

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element A4/A.4.2_Occupiers_and_users

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</tr>
<tr>
<td>children</td>
<td>Company First_name Last_name Street Postcode City Phone Telefax E-Mail</td>
</tr>
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element A4/A.4.3_General_manager_or_administrator

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element A4/A.4.4_Briefing_consultants

```xml
<xs:element name="A.4.4_Briefing_consultants" type="Adress_information_A"/>
```
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Appendix B

**element A4/A.4.5_Designer**

```
<xs:element name="A.4.5_Designer" type="Adress_information_A"/>
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**element A4/A.4.6_Other_consultants**

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```
element A4/A.4.7_Builder

```xml
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complexType A5

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<xs:element name="A.5.3_Local_government"/>
<xs:element name="A.5.4_Town_planning_and_building_authorities"/>
<xs:element name="A.5.5_Financiers"/>
<xs:element name="A.5.6_Groups_or_persons_with_special_interest"/>
<xs:element name="A.5.7_Site_owners_or_tenants"/>
<xs:element name="A.5.8_Neighbours_and_their_consultants"/>
<xs:element name="A.5.9_Media"/>
<xs:element name="A.5.10_Insurers"/>
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used by element Briefing_checklist_A/A.5_Identity_of_other_related_groups
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Appendix B

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<th>documentation</th>
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<td></td>
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<td></td>
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**Element A5/A.5.1 Central government**

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<td>Last_name</td>
</tr>
<tr>
<td></td>
<td>Street</td>
</tr>
<tr>
<td></td>
<td>Postcode</td>
</tr>
<tr>
<td></td>
<td>City</td>
</tr>
<tr>
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<td>Phone</td>
</tr>
<tr>
<td></td>
<td>Telefax</td>
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<td>E-Mail</td>
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element A5/A.5.2_National_and_international_agencies

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<td>content complex</td>
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<tr>
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element A5/A.5.3_Local_government

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element A5/A.5.4_Town_planning_and_buildingAuthorities

diagram

A5/A.5.4_Town_planning_and_buildingAuthorities

Diagram showing the structure of A5/A.5.4_Town_planning_and_buildingAuthorities with properties:
- type: Adress_information_A
- content: complex
- children: Company, First_name, Last_name, Street, Postcode, City, Phone, Telex, E-Mail

source:
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element A5/A.5.5_Financiers

diagram

A5/A.5.5_Financiers

Diagram showing the structure of A5/A.5.5_Financiers with properties:
- type: Adress_information_A
- minOcc: 1
- maxOcc: unbounded
- content: complex
- children: Company, First_name, Last_name, Street, Postcode, City, Phone, Telex, E-Mail

source:
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element A5/A.5.6_Groups_or_persons_with_special_interest

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element A5/A.5.7_Site_owners_or_tenants

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<xs:element name="A.5.7_Site_owners_or_tenants" type="Adress_information_A" maxOccurs="unbounded"/>
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element A5/A.5.8_Neighbours_and_their_consultants

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element A5/A.5.9_Media

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element A5/A.5.10_Insurers

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used by elements

- A4/A.4.1 Client
- A4/A.4.2 Occupiers_and_users
- A4/A.4.3 General_manager_or_administrator
- A4/A.4.4 Briefing_consultants
- A4/A.4.5 Designer
- A4/A.4.6 Other_consultants
- A4/A.4.7 Builder
- A5/A.5.10 Insurers
- A5/A.5.1 Central_government
- A5/A.5.2 National_and_international_agencies
- A5/A.5.3 Local_government
- A5/A.5.4 Town_planning_and_building_authorities
- A5/A.5.5 Financiers
- A5/A.5.6 Groups_or_persons_with_special_interest
- A5/A.5.7 Site_owners_or_tenants
- A5/A.5.8 Neighbours_and_their_consultants
- A5/A.5.9 Media

annotation documentation

Adressen der Beteiligten und anderen Einflußgruppen
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Appendix B

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Appendix B

**element Address_information_A/Last_name**

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**element Address_information_A/Street**

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**element Address_information_A/Postcode**

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**element Address_information_A/City**

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**element Address_information_A/Phone**

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Appendix B

### Element: Adresse_information_A/Telefax

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<tr>
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<th>Facets</th>
<th>Source</th>
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### Element: Adresse_information_A/E-Mail

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<th>Type</th>
<th>Properties</th>
<th>Facets</th>
<th>Source</th>
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| ![E-Mail](email.png) | restriction of xs:string | content simple | pattern [A-Za-z0-9._+\-\.]@[A-Za-z0-9._+\-\.]\.[A-Za-z0-9._+\-\.] | name="E-Mail">

### ComplexType: B1

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</tbody>
</table>

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Appendix B

<table>
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<td></td>
<td>&lt;xs:element name=&quot;B.1.1_Participants&quot; type=&quot;B1&quot;/&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;xs:element name=&quot;B.1.2_Related_groups_organization&quot;/&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;xs:element name=&quot;B.1.3_Design_evaluation_procedures&quot;/&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;xs:element name=&quot;B.1.4_Quality_control&quot;/&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;/xs:sequence&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;/xs:complexType&gt;</td>
</tr>
</tbody>
</table>

**element B1/B.1.1_Participants**

**diagram**

```
B1_1
```

- **type**: B1_1
- **properties**: content complex
- **children**: Client Occupiers_and_users General_manager Briefing_consultant Designer Builder

**source**

```
<xs:element name="B.1.1_Participants" type="B1_1"/>
```

**element B1/B.1.2_Related_groups_organization**

**diagram**

```
B.1.2_Related_groups_organization
```

**source**

```
<xs:element name="B.1.2_Related_groups_organization"/>
```

**element B1/B.1.3_Design_evaluation_procedures**

**diagram**

```
B.1.3_Design_evaluation_procedures
```

**source**

```
<xs:element name="B.1.3_Design_evaluation_procedures"/>
```
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element B1/B.1.4_Quality_control

diagram

source

complexType B1_1

diagram

children

used by

annotation
documentation
Participants

source

element B1_1/Client

diagram

type B1_1_definition

properties content complex

children Competence Responsibility Role Expert_knowledge

source

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element B1_1/Occupiers_and_users

<table>
<thead>
<tr>
<th>diagram</th>
<th>B1_1_definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>B1_1_definition</td>
</tr>
<tr>
<td>properties</td>
<td>content complex</td>
</tr>
<tr>
<td>children</td>
<td>Competence Responsibility Role Expert_knowledge</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Occupiers_and_users&quot; type=&quot;B1_1_definition&quot;/&gt;</td>
</tr>
</tbody>
</table>

element B1_1/General_manager

<table>
<thead>
<tr>
<th>diagram</th>
<th>B1_1_definition</th>
</tr>
</thead>
<tbody>
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<td>B1_1_definition</td>
</tr>
<tr>
<td>properties</td>
<td>content complex</td>
</tr>
<tr>
<td>children</td>
<td>Competence Responsibility Role Expert_knowledge</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;General_manager&quot; type=&quot;B1_1_definition&quot;/&gt;</td>
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</tbody>
</table>

element B1_1/Briefing_consultant

<table>
<thead>
<tr>
<th>diagram</th>
<th>B1_1_definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>B1_1_definition</td>
</tr>
<tr>
<td>properties</td>
<td>content complex</td>
</tr>
<tr>
<td>children</td>
<td>Competence Responsibility Role Expert_knowledge</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Briefing_consultant&quot; type=&quot;B1_1_definition&quot;/&gt;</td>
</tr>
</tbody>
</table>
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element B1.1/Designer

```
<xs:element name="Designer" type="B1.1_definition"/>
```

element B1.1/Builder

```
<xs:element name="Builder" type="B1.1_definition"/>
```

complexType B1.1_definition

```
<xs:complexType name="B1.1_definition">
  <xs:annotation>
    <xs:documentation>Further description to B1.1.</xs:documentation>
  </xs:annotation>
  <xs:sequence>
    <xs:element name="Competence" type="xs:string"/>
    <xs:element name="Responsibility" type="xs:string"/>
    <xs:element name="Role" type="xs:string"/>
    <xs:element name="Expert_knowledge" type="xs:string"/>
  </xs:sequence>
</xs:complexType>
```
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| <xs:element name="Expert_knowledge" type="xs:string"/> |
| <xs:sequence> |
| <xs:complexType> |

**element B1_1_definition/Competence**

<table>
<thead>
<tr>
<th>diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>#Competence</td>
</tr>
</tbody>
</table>

| type | xs:string |
| properties | content simple |
| source | <xs:element name="Competence" type="xs:string"/> |

**element B1_1_definition/Responsibility**

<table>
<thead>
<tr>
<th>diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>#Responsibility</td>
</tr>
</tbody>
</table>

| type | xs:string |
| properties | content simple |
| source | <xs:element name="Responsibility" type="xs:string"/> |

**element B1_1_definition/Role**

<table>
<thead>
<tr>
<th>diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>#Role</td>
</tr>
</tbody>
</table>

| type | xs:string |
| properties | content simple |
| source | <xs:element name="Role" type="xs:string"/> |

**element B1_1_definition/Expert_knowledge**

<table>
<thead>
<tr>
<th>diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>#Expert_knowledge</td>
</tr>
</tbody>
</table>

| type | xs:string |
| properties | content simple |
| source | <xs:element name="Expert_knowledge" type="xs:string"/> |
complexType B2

```
<xs:complexType name="B2">
  <xs:annotation>
    <xs:documentation>Laws, standards and codes</xs:documentation>
  </xs:annotation>
  <xs:sequence>
    <xs:element name="B.2.1_Town_planning">
      <xs:complexType>
        <xs:sequence>
          <xs:element name="National_regional_and_local_plans" type="xs:string"/>
          <xs:element name="Zoning" type="xs:string"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="B.2.2_Legal_restrictions_on_the_site_or_buildings">
      <xs:complexType>
        <xs:sequence>
          <xs:element name="Covenants" type="xs:string"/>
          <xs:element name="Rights_of_way" type="xs:string"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="B.2.3_Occupancy_laws">
      <xs:complexType>
        <xs:sequence>
          <xs:element name="Health_and_safety" type="xs:string"/>
          <xs:element name="Employment" type="xs:string"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="B.2.4_Finance">
      <xs:annotation>
        <xs:documentation>This subheading should be reserved for financial regulations. Details of the budgets and other matters directly related to the project should be noted under B.3.</xs:documentation>
      </xs:annotation>
    </xs:element>
    <xs:element name="B.2.5_Building_or_design_regulation_and_codes">
    </xs:element>
    <xs:element name="B.2.6_Environmental_and_pollution_regulations">
    </xs:element>
    <xs:element name="B.2.7_Political_administrative">
    </xs:element>
    <xs:element name="B.2.8_Social_and_cultural">
    </xs:element>
  </xs:sequence>
</xs:complexType>
```

children:
- B.2.1_Town_planning
- B.2.2_Legal_restrictions_on_the_site_or_buildings
- B.2.3_Occupancy_laws
- B.2.4_Finance
- B.2.5_Building_or_design_regulation_and_codes
- B.2.6_Environmental_and_pollution_regulations
- B.2.7_Political_administrative
- B.2.8_Social_and_cultural

used by:
- element: Briefing_checklist_B/B.2_Laws_standards_and_codes

source:
- <xs:complexType name="B2">
  <xs:annotation>
    <xs:documentation>Laws, standards and codes</xs:documentation>
  </xs:annotation>
  <xs:sequence>
    <xs:element name="B.2.1_Town_planning">
      <xs:complexType>
        <xs:sequence>
          <xs:element name="National_regional_and_local_plans" type="xs:string"/>
          <xs:element name="Zoning" type="xs:string"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="B.2.2_Legal_restrictions_on_the_site_or_buildings">
      <xs:complexType>
        <xs:sequence>
          <xs:element name="Covenants" type="xs:string"/>
          <xs:element name="Rights_of_way" type="xs:string"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="B.2.3_Occupancy_laws">
      <xs:complexType>
        <xs:sequence>
          <xs:element name="Health_and_safety" type="xs:string"/>
          <xs:element name="Employment" type="xs:string"/>
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    </xs:element>
    <xs:element name="B.2.4_Finance">
      <xs:annotation>
        <xs:documentation>This subheading should be reserved for financial regulations. Details of the budgets and other matters directly related to the project should be noted under B.3.</xs:documentation>
      </xs:annotation>
    </xs:element>
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    </xs:element>
    <xs:element name="B.2.6_Environmental_and_pollution_regulations">
    </xs:element>
    <xs:element name="B.2.7_Political_administrative">
    </xs:element>
    <xs:element name="B.2.8_Social_and_cultural">
    </xs:element>
  </xs:sequence>
</xs:complexType>
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Appendix B

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Appendix B

**element B2/B.2.1_Town_planning/National_regional_and_local_plans**

<table>
<thead>
<tr>
<th>diagram</th>
<th>National_regional_and_local_plans</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;National_regional_and_local_plans&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>

**element B2/B.2.1_Town_planning/Zoning**

<table>
<thead>
<tr>
<th>diagram</th>
<th>Zoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Zoning&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>

**element B2/B.2.2_Legal_restrictions_on_the_site_or_buildings**

<table>
<thead>
<tr>
<th>diagram</th>
<th>B2_B.2_Legal_restrictions_on_the_site_or_buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>properties</td>
<td>content complex</td>
</tr>
<tr>
<td>children</td>
<td>Covenants Rights_of_way</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;B.2.2_Legal_restrictions_on_the_site_or_buildings&quot;&gt;</td>
</tr>
<tr>
<td></td>
<td><a href="">xs:complexType</a></td>
</tr>
<tr>
<td></td>
<td><a href="">xs:sequence</a></td>
</tr>
<tr>
<td></td>
<td>&lt;xs:element name=&quot;Covenants&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;xs:element name=&quot;Rights_of_way&quot; type=&quot;xs:string&quot;/&gt;</td>
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<tr>
<td></td>
<td>&lt;/xs:sequence&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;/xs:complexType&gt;</td>
</tr>
</tbody>
</table>

**element B2/B.2.2_Legal_restrictions_on_the_site_or_buildings/Covenants**

<table>
<thead>
<tr>
<th>diagram</th>
<th>Covenants</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Covenants&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>
element B2/B.2.2_Legal_restrictions_on_the_site_or_buildings/Rights_of_way

<table>
<thead>
<tr>
<th>diagram</th>
<th>Rights_of_way</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td><code>&lt;xs:element name=&quot;Rights_of_way&quot; type=&quot;xs:string&quot;/&gt;</code></td>
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</tbody>
</table>

element B2/B.2.3_Occupancy_laws

<table>
<thead>
<tr>
<th>diagram</th>
<th>B.2.3_Occupancy_laws</th>
</tr>
</thead>
<tbody>
<tr>
<td>properties</td>
<td>content complex</td>
</tr>
<tr>
<td>children</td>
<td>Health_and_safety Employment</td>
</tr>
<tr>
<td>source</td>
<td><code>&lt;xs:element name=&quot;B.2.3_Occupancy_laws&quot; type=&quot;xs:string&quot;/&gt;</code> <code>&lt;xs:complexType&gt;</code> <code>&lt;xs:sequence&gt;</code> <code>&lt;xs:element name=&quot;Health_and_safety&quot; type=&quot;xs:string&quot;/&gt;</code> <code>&lt;xs:element name=&quot;Employment&quot; type=&quot;xs:string&quot;/&gt;</code> <code>&lt;xs:sequence&gt;</code> <code>&lt;xs:complexType&gt;</code> <code>&lt;xs:element&gt;</code></td>
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</tbody>
</table>

element B2/B.2.3_Occupancy_laws/Health_and_safety

<table>
<thead>
<tr>
<th>diagram</th>
<th>Health_and_safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td><code>&lt;xs:element name=&quot;Health_and_safety&quot; type=&quot;xs:string&quot;/&gt;</code></td>
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</table>

element B2/B.2.3_Occupancy_laws/Employment

<table>
<thead>
<tr>
<th>diagram</th>
<th>Employment</th>
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<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td><code>&lt;xs:element name=&quot;Employment&quot; type=&quot;xs:string&quot;/&gt;</code></td>
</tr>
</tbody>
</table>
element B2/B.2.4_Finance

Diagram

This subheading should be reserved for financial regulations. Details of the budgets and other matters directly related to the project should be noted under B.3.

Source

<xs:element name="B.2.4_Finance">
   <xs:annotation>
      <xs:documentation>This subheading should be reserved for financial regulations. Details of the budgets and other matters directly related to the project should be noted under B.3.</xs:documentation>
   </xs:annotation>
   <xs:complexType>
      <xs:sequence>
         <xs:element name="Grants_and_subsidies" type="xs:string"/>
         <xs:element name="Import_and_export_regulations" type="xs:string"/>
         <xs:element name="Taxation" type="xs:string"/>
      </xs:sequence>
   </xs:complexType>
</xs:element>

element B2/B.2.4_Finance/Grants_and_subsidies

Diagram

Source

<xs:element name="Grants_and_subsidies" type="xs:string"/>

element B2/B.2.4_Finance/Import_and_export_regulations

Diagram

Source

<xs:element name="Import_and_export_regulations" type="xs:string"/>

element B2/B.2.4_Finance/Taxation

Diagram

Source

<xs:element name="Taxation" type="xs:string"/>
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<table>
<thead>
<tr>
<th>properties</th>
<th>content</th>
<th>simple</th>
</tr>
</thead>
<tbody>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Taxation&quot; type=&quot;xs:string&quot;/&gt;</td>
<td></td>
</tr>
</tbody>
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**element B2/B.2.5_Building_or_design_regulation_and_codes**

```
<xs:element name="B.2.5_Building_or_design_regulation_and_codes">
  <xs:complexType>
    <xs:sequence>
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  </xs:complexType>
</xs:element>
```

**element B2/B.2.5_Building_or_design_regulation_and_codes/International_national_codes**

```
<xs:element name="International_national_codes" type="xs:string"/>
```

**element B2/B.2.6_Environmental_and_pollution_regulations**

```
<xs:element name="B.2.6_Environmental_and_pollution_regulations">
  <xs:complexType>
    <xs:sequence>
      <xs:element name="Air_water_noise_energy_and_waste_disposal" type="xs:string"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
```
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Appendix B

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>B2/B.2.6_Environmental_and_pollution_regulations/Air_water_noise_energy_and_waste_disposal</td>
<td>Diagram showing environmental and pollution regulations with properties and source code.</td>
</tr>
<tr>
<td>B2/B.2.7_Political_administrative</td>
<td>Diagram showing political administrative diagram with properties and children.</td>
</tr>
<tr>
<td>B2/B.2.7_Political_administrative/Political_approval_procedures</td>
<td>Diagram showing political approval procedures with properties and source code.</td>
</tr>
<tr>
<td>B2/B.2.7_Political_administrative/National_and_local_political_interest</td>
<td>Diagram showing national and local political interest with properties and source code.</td>
</tr>
</tbody>
</table>
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element B2/B2.8_Social_and_cultural

```
<xs:element name="B2.8_Social_and_cultural">
  <xs:complexType>
    <xs:sequence>
      <xs:element name="Hearings_and_tribunals" type="xs:string"/>
      <xs:element name="Organized_interest_groups" type="xs:string"/>
      <xs:element name="Other_influences_groups_or_media" type="xs:string"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
```

element B2/B2.8_Social_and_cultural/Hearings_and_tribunals

```
<xs:element name="Hearings_and_tribunals" type="xs:string"/>
```

element B2/B2.8_Social_and_cultural/Organized_interest_groups

```
<xs:element name="Organized_interest_groups" type="xs:string"/>
```

element B2/B2.8_Social_and_cultural/Other_influences_groups_or_media

```
<xs:element name="Other_influences_groups_or_media" type="xs:string"/>
```
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complexType B3

```
<complexType name="B3">
  <annotation>
    <documentation>Financial and time contraints</documentation>
  </annotation>
  <sequence>
    <element name="B.3.1_Financing_the_project" type="xs:string"/>
    <element name="B.3.2_Budgets" type="xs:string"/>
    <element name="B.3.3_Costs_in_use" type="xs:string"/>
    <element name="B.3.4_Target_dates" type="xs:string"/>
    <element name="B.3.5_Life_expectancy" type="xs:string"/>
    <element name="B.3.6_Financial_and_time_risk" type="xs:string"/>
  </sequence>
</complexType>
```

```
<xs:complexType name="B.3.1_Financing_the_project">
  <xs:annotation>
    <xs:documentation>Finance is distinct from budgets or costs. Budgets are the financial allocation made to cover predicted costs. Costs are the consequence of decisions made during the briefing and design process. Although predicted costs are not included in the checklist, they should be reviewed at frequent and agreed intervals for comparison with budgets and available finance. Most actual costs will only be incurred once construction starts. Actual costs should also be monitored and recorded.</xs:documentation>
  </xs:annotation>
</xs:complexType>

```
<xs:complexType name="B.3.2_Budgets">
  <xs:annotation>
    <xs:documentation>Finance is distinct from budgets or costs. Budgets are the financial allocation made to cover predicted costs. Costs are the consequence of decisions made during the briefing and design process. Although predicted costs are not included in the checklist, they should be reviewed at frequent and agreed intervals for comparison with budgets and available finance. Most actual costs will only be incurred once construction starts. Actual costs should also be monitored and recorded.</xs:documentation>
  </xs:annotation>
</xs:complexType>

```
<xs:complexType name="B.3.3_Costs_in_use">
  <xs:annotation>
    <xs:documentation>For complex projects, planning the sequence of events by critical path</xs:documentation>
  </xs:annotation>
</xs:complexType>

```
<xs:complexType name="B.3.4_Target_dates">
  <xs:annotation>
    <xs:documentation>Planning the sequence of events by critical path</xs:documentation>
  </xs:annotation>
</xs:complexType>

```
<xs:complexType name="B.3.5_Life_expectancy">
  <xs:annotation>
    <xs:documentation>Life expectancy</xs:documentation>
  </xs:annotation>
</xs:complexType>

```
<xs:complexType name="B.3.6_Financial_and_time_risk">
  <xs:annotation>
    <xs:documentation>Financial and time contraints</xs:documentation>
  </xs:annotation>
</xs:complexType>
```
For complex projects, planning the sequence of events by critical path analysis will be necessary in order to identify priorities. Information on building phasing should include the sequence and size of the accommodation needed both as part of the current project and for any future planned changes (see B.3.5).
Finance is distinct from budgets or costs. Budgets are the financial allocation made to cover predicted costs. Costs are the consequence of decisions made during the briefing and design process. Although predicted costs are not included in the checklist, they should be reviewed at frequent and agreed intervals for comparison with budgets and available finance. Most actual costs will only be incurred once construction starts. Actual costs should also be monitored and recorded.
Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

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Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

Appendix B

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Ph.D. thesis
CHRISTIAN BAIER

254
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Appendix B

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For complex projects, planning the sequence of events by critical path analysis will be necessary in order to identify priorities. Information on building phasing should include the sequence and size of the accommodation needed both as part of the current project and for any future planned changes (see B.3.5).
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### Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

**Appendix B**

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Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

Appendix B

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Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

### Appendix B

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element B4/B.4.1_Project_history/Political_attitudes

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</tr>
<tr>
<td>children</td>
<td>Client_and_user_activities Existing_sites_facilities_and_buildings On-going_investigations</td>
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<tr>
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Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

Appendix B

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Element: B4/Commitments/Organizational

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Appendix B

source `<xs:element name="Organizational" type="xs:string"/>

element B4/Commitments/Social

diagram 🍀 Social

type `xs:string`

properties content simple

source `<xs:element name="Social" type="xs:string"/>

element B4/Commitments/Contractual

diagram 🍀 Contractual

type `xs:string`

properties content simple

source `<xs:element name="Contractual" type="xs:string"/>

complexType B5

diagram

children B.5.1_Site_availability B.5.2_Commercial_and_social B.5.3_Environmental_data B.5.4_Infrastructure B.5.5_Geophysical_data B.5.6_Ground_characteristics B.5.7_Existing_buildings

used by element Briefing_checklist_B/B.5_Influences_of_site_and_surroundings

annotation documentation Influences of site and surroundings

source `<xs:complexType name="B5">
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    <xs:element name="Rental_or_purchase" type="xs:string"/>
  </xs:sequence>
</xs:complexType>`
Both trends and existing characteristics should be considered.

The existing transport and services infrastructure is an important criterion which may need consideration at both site and regional levels. Consider both trends and existing characteristics.

The geographical and topographical data include:

- **Microclimate**
- **Local climate**
- **Hydrological**
- **Seismic**
- **Acoustic**
- **Geographical**
- **Topographical**
- **Extent area**
- **Orientation**
- **landscape or vegetation**

The commercial and social data include:

- **Catchment areas**
- **Hinterland**
- **Neighbourhood**
- **Population**
- **Users**
- **Public or privat**
- **Obligations**
- **Amenities and disadvantages**

The environmental data include:

- **Microclimate**
- **Local climate**
- **Hydrological**
- **Seismic**
- **Acoustic**
- **Geographical**
- **Topographical**
- **Extent area**
- **Orientation**
- **landscape or vegetation**
Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

Appendix B

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element B5/B.5.1_Site_availability

```

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element B5/B.5.1_Site_availability/Ownership_and_previous_use

diagram

Ownership_and_previous_use

type xs:string

properties content simple

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element B5/B.5.1_Site_availability/Rental_or_purchase

diagram

Rental_or_purchase

type xs:string

properties content simple

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element B5/B.5.1_Site_availability/Legal_conditions

diagram

Legal_conditions

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properties content simple

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element B5/B.5.1_Site_availability/Boundaries

diagram

Boundaries

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properties content simple

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element B5/B.5.1_Site_availability/Acces_to_the_site

diagram

Acces_to_the_site

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properties content simple

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element B5/B.5.1_Site_availability/Availability_of_surveys

diagram

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element B5/B.5.2_Commercial_and_social

diagram

| properties | content complex |
| children | Catchment_areas Hinterland Neighbourhood Population Users Public_or_privat Obligations Amenities_and_disadvantages |
| annotation documentation | Both trends and existing characteristics should be considered. |
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|         | `<xs:element name="Neighbourhood" type="xs:string"/>` |
|         | `<xs:element name="Population" type="xs:string"/>` |
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element B5/B.5.2_Commercial_and_social/Catchment_areas

diagram

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Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

Appendix B

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**element B5/B.5.2_Commercial_and_social/Hinterland**

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element B5/B.5.2_Commercial_and_social/Amenities_and_disadvantages

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```

element B5/B.5.3_Environmental_data/Microclimate

```xml
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  <pre>Microclimate Local_climate Hydrological Seismic Acoustic</pre>
</xs:element>
```
Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

Appendix B

source

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element B5/B.5.3_Environmental_data/Local_climate
diagram

<xs:element name="Local_climate" type="xs:string"/>

type xs:string

properties content simple

source <xs:element name="Local_climate" type="xs:string"/>

element B5/B.5.3_Environmental_data/Hydrological
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type xs:string

properties content simple

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element B5/B.5.3_Environmental_data/Seismic
diagram

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type xs:string

properties content simple

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element B5/B.5.3_Environmental_data/Acoustic
diagram

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type xs:string

properties content simple

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element B5/B.5.4_Infrastructure
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<xs:element name="Utility_services" type="xs:string"/>

The existing transport and services infrastructure is

properties content complex

children Facilities Utility_services

annotation documentation
The existing transport and services infrastructure is an important criterion which may need consideration at both site and regional Levels. Consider both trends and existing characteristics.

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        <xs:documentation>The existing transport and services infrastructure is an important criterion which may need consideration at both site and regional Levels. Consider both trends and existing characteristics.</xs:documentation>
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            <xs:element name="Utility_services" type="xs:string"/>
        </xs:sequence>
    </xs:complexType>
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```

**element B5/B.5.4_Infrastructure/Facilities**

- **diagram**
  - Facilities

- **type** xs:string

- **properties** content simple

- **source**
  - `<xs:element name="Facilities" type="xs:string"/>

**element B5/B.5.4_Infrastructure/Utility_services**

- **diagram**
  - Utility_services

- **type** xs:string

- **properties** content simple

- **source**
  - `<xs:element name="Utility_services" type="xs:string"/>

**element B5/B.5.5_Geophysical_data**

- **diagram**
  - B.5.5_Geophysical_data

- **properties** content complex

- **children**
  - Geographical Topographical Extent_area Orientation landscape_or_vegetation

- **source**
  - `<xs:element name="B.5.5_Geophysical_data">
    <xs:complexType>
      <xs:sequence>
```

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```
<xs:element name="Geographical" type="xs:string"/>
<xs:element name="Topographical" type="xs:string"/>
<xs:element name="Extent_area" type="xs:string"/>
<xs:element name="Orientation" type="xs:string"/>
<xs:element name="landscape_or_vegetation" type="xs:string"/>
</xs:sequence>
</xs:complexType>
</xs:element>
```

**element B5/B.5_Geophysical_data/Geographical**

<table>
<thead>
<tr>
<th>diagram</th>
<th>Geographical</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Geographical&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>

**element B5/B.5_Geophysical_data/Topographical**

<table>
<thead>
<tr>
<th>diagram</th>
<th>Topographical</th>
</tr>
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<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Topographical&quot; type=&quot;xs:string&quot;/&gt;</td>
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</table>

**element B5/B.5_Geophysical_data/Extent_area**

<table>
<thead>
<tr>
<th>diagram</th>
<th>Extent_area</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Extent_area&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>

**element B5/B.5_Geophysical_data/Orientation**

<table>
<thead>
<tr>
<th>diagram</th>
<th>Orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Orientation&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>

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element B5/B.5.5_Geophysical_data/landscape_or_vegetation

<table>
<thead>
<tr>
<th>diagram</th>
<th>landscape_or_vegetation</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;landscape_or_vegetation&quot; type=&quot;xs:string&quot;/&gt;</td>
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</tbody>
</table>

element B5/B.5.6_Ground_characteristics

<table>
<thead>
<tr>
<th>diagram</th>
<th>B.5.6_Ground_characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content complex</td>
</tr>
<tr>
<td>children</td>
<td>Soil_composition Bearing_capacity Soil_contamination Water_table</td>
</tr>
</tbody>
</table>

element B5/B.5.6_Ground_characteristics/Soil_composition

<table>
<thead>
<tr>
<th>diagram</th>
<th>Soil_composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Soil_composition&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>

element B5/B.5.6_Ground_characteristics/Bearing_capacity

<table>
<thead>
<tr>
<th>diagram</th>
<th>Bearing_capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Bearing_capacity&quot;/&gt;</td>
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element B5/B.5.6_Ground_characteristics/Soil_contamination

<table>
<thead>
<tr>
<th>diagram</th>
<th>Soil_contamination</th>
</tr>
</thead>
<tbody>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Soil_contamination&quot;/&gt;</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>type</th>
<th>xs:string</th>
</tr>
</thead>
<tbody>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Soil_contamination&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>

**element B5/B.5.6_Ground_characteristics/Water_table**

<table>
<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Water_table&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>

**element B5/B.5.7_Existing_buildings**

```
<xs:element name="B.5.7_Existing_buildings">
  <xs:complexType>
    <xs:sequence>
      <xs:element name="Use"/>
      <xs:element name="Area" type="xs:string"/>
      <xs:element name="Form_of_construction" type="xs:string"/>
      <xs:element name="State_of_repair" type="xs:string"/>
      <xs:element name="Adaptability" type="xs:string"/>
      <xs:element name="Availability_of_a_structural_survey" type="xs:string"/>
      <xs:element name="Protected_status" type="xs:string"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
```

**element B5/B.5.7_Existing_buildings/Use**

```
 <xs:element name="Use"/>
```

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element B5/B.5.7_Existing_buildings/Area

diagram

<table>
<thead>
<tr>
<th>type</th>
<th>xs:string</th>
</tr>
</thead>
<tbody>
<tr>
<td>properties</td>
<td>content</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Area&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>

element B5/B.5.7_Existing_buildings/Form_of_construction

diagram

<table>
<thead>
<tr>
<th>type</th>
<th>xs:string</th>
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</thead>
<tbody>
<tr>
<td>properties</td>
<td>content</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Form_of_construction&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>

element B5/B.5.7_Existing_buildings/State_of_repair

diagram

<table>
<thead>
<tr>
<th>type</th>
<th>xs:string</th>
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</thead>
<tbody>
<tr>
<td>properties</td>
<td>content</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;State_of_repair&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>

element B5/B.5.7_Existing_buildings/Adaptability

diagram

<table>
<thead>
<tr>
<th>type</th>
<th>xs:string</th>
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<tbody>
<tr>
<td>properties</td>
<td>content</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Adaptability&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>

element B5/B.5.7_Existing_buildings/Availability_of_a_structural_survey

diagram

<table>
<thead>
<tr>
<th>type</th>
<th>xs:string</th>
</tr>
</thead>
<tbody>
<tr>
<td>properties</td>
<td>content</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Availability_of_a_structural_survey&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>
element B5/B.5.7_Existing_buildings/Protected_status

diagram

<table>
<thead>
<tr>
<th>type</th>
<th>xs:string</th>
</tr>
</thead>
<tbody>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Protected_status&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>

complexType B6

diagram

<table>
<thead>
<tr>
<th>children</th>
<th>element B.6.1_Purpose B.6.2_Size B.6.3_Context B.6.4_Future_changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>used by</td>
<td>element Briefing_checklist_B/B.6_Clients_future.enterprise</td>
</tr>
<tr>
<td>annotation</td>
<td>documentation Clients future Enterprise</td>
</tr>
</tbody>
</table>
| source            | <xs:complexType name="B6">  
|                   | <xs:annotation>Clients future Enterprise</xs:documentation>  
|                   | <xs:sequence>  
|                   | <xs:element name="B.6.1_Purpose">  
|                   | <xs:complexType>  
|                   | <xs:sequence>  
|                   | <xs:element name="Company_profile" type="xs:string"/>  
|                   | <xs:element name="Strategic_aims" type="xs:string"/>  
|                   | <xs:element name="Priorities" type="xs:string"/>  
|                   | <xs:element name="Image" type="xs:string"/>  
|                   | <xs:element name="New_areas_of_activity" type="xs:string"/>  
|                   | </xs:sequence>  
|                   | </xs:complexType>  
|                   | </xs:element>  
|                   | <xs:element name="B.6.2_Size">  
|                   | <xs:complexType>  
|                   | <xs:sequence>  
|                   | <xs:element name="Relative_to_other_enterprises" type="xs:string"/>  
|                   | <xs:element name="Market_share_and_turnover" type="xs:string"/>  
|                   | <xs:element name="Number_of_employees" type="xs:string"/>  
|                   | </xs:sequence>  
|                   | </xs:complexType>  
|                   | </xs:element>  
|                   | <xs:element name="B.6.3_Context">  
|                   | <xs:complexType>  
|                   | <xs:sequence>  
|                   | <xs:element name="National_and_local_trends" type="xs:string"/>  
|                   | <xs:element name="Social" type="xs:string"/>  
|                   | <xs:element name="Commercial" type="xs:string"/>  
|                   | <xs:element name="Technological" type="xs:string"/>  
|                   | <xs:element name="Availability_of_resources" type="xs:string"/>  
|                   | </xs:sequence>  
|                   | </xs:complexType>  
|                   | </xs:element>  
|                   | <xs:element name="B.6.4_Future_changes">  
|                   | <xs:complexType>  
|                   | </xs:element>  
|                   | </xs:complexType> |

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xml_element B6/B.6.1_Purpose

```
<xs:complexType>
    <xs:sequence>
        <xs:element name="Company_profile" type="xs:string"/>
        <xs:element name="Strategic_aims" type="xs:string"/>
        <xs:element name="Priorities" type="xs:string"/>
        <xs:element name="Image" type="xs:string"/>
        <xs:element name="New_areas_of_activity" type="xs:string"/>
    </xs:sequence>
</xs:complexType>
```

element B6/B.6.1_Purpose/Company_profile

```
<xs:element name="Company_profile" type="xs:string"/>
```

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### element B6/B.6.1_Purpose/Strategic_aims
```
<table>
<thead>
<tr>
<th>diagram</th>
<th>Strategic_aims</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td><code>&lt;xs:element name=&quot;Strategic_aims&quot; type=&quot;xs:string&quot;/&gt;</code></td>
</tr>
</tbody>
</table>
```

### element B6/B.6.1_Purpose/Priorities
```
<table>
<thead>
<tr>
<th>diagram</th>
<th>Priorities</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td><code>&lt;xs:element name=&quot;Priorities&quot; type=&quot;xs:string&quot;/&gt;</code></td>
</tr>
</tbody>
</table>
```

### element B6/B.6.1_Purpose/Image
```
<table>
<thead>
<tr>
<th>diagram</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td><code>&lt;xs:element name=&quot;Image&quot; type=&quot;xs:string&quot;/&gt;</code></td>
</tr>
</tbody>
</table>
```

### element B6/B.6.1_Purpose/New_areas_of_activity
```
<table>
<thead>
<tr>
<th>diagram</th>
<th>New_areas_of_activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td><code>&lt;xs:element name=&quot;New_areas_of_activity&quot; type=&quot;xs:string&quot;/&gt;</code></td>
</tr>
</tbody>
</table>
```

### element B6/B.6.2_Size
```
<table>
<thead>
<tr>
<th>diagram</th>
<th>B.6.2_Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>properties</td>
<td>content complex</td>
</tr>
<tr>
<td>children</td>
<td>Relative_to_other_enterprises Market_share_and_turnover Number_of_employees</td>
</tr>
<tr>
<td>source</td>
<td><code>&lt;xs:element name=&quot;B.6.2_Size&quot;/&gt;</code></td>
</tr>
</tbody>
</table>
```

---

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| <xs:element name="Market_share_and_turnover" type="xs:string"/> |
| <xs:element name="Number_of_employees" type="xs:string"/> |
| <xs:sequence> |
| </xs:complexType> |
| </xs:element> |

**element B6/B.6.2_Size/Relative_to_other_enterprises**

<table>
<thead>
<tr>
<th>diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>#Relative_to_other_enterprises</td>
</tr>
<tr>
<td>type</td>
</tr>
<tr>
<td>properties</td>
</tr>
<tr>
<td>source</td>
</tr>
</tbody>
</table>

**element B6/B.6.2_Size/Market_share_and_turnover**

<table>
<thead>
<tr>
<th>diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>#Market_share_and_turnover</td>
</tr>
<tr>
<td>type</td>
</tr>
<tr>
<td>properties</td>
</tr>
<tr>
<td>source</td>
</tr>
</tbody>
</table>

**element B6/B.6.2_Size/Number_of_employees**

<table>
<thead>
<tr>
<th>diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>#Number_of_employees</td>
</tr>
<tr>
<td>type</td>
</tr>
<tr>
<td>properties</td>
</tr>
<tr>
<td>source</td>
</tr>
</tbody>
</table>

**element B6/B.6.3_Context**

<table>
<thead>
<tr>
<th>diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.6.3_Context ← National_and_local_trends Social Commercial Technological Availability_of_resources</td>
</tr>
<tr>
<td>properties</td>
</tr>
<tr>
<td>children</td>
</tr>
<tr>
<td>source</td>
</tr>
<tr>
<td><a href="">xs:complexType</a></td>
</tr>
<tr>
<td><a href="">xs:sequence</a></td>
</tr>
<tr>
<td>&lt;xs:element name=&quot;National_and_local_trends&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>element B6/B.6.3_Context/National_and_local_trends</th>
<th>diagram</th>
<th>type</th>
<th>properties</th>
<th>source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image1" alt="National_and_local_trends" /></td>
<td>xs:string</td>
<td>content simple</td>
<td>&lt;xs:element name=&quot;National_and_local_trends&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>element B6/B.6.3_Context/Social</th>
<th>diagram</th>
<th>type</th>
<th>properties</th>
<th>source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image2" alt="Social" /></td>
<td>xs:string</td>
<td>content simple</td>
<td>&lt;xs:element name=&quot;Social&quot; type=&quot;xs:string&quot;/&gt;</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>element B6/B.6.3_Context/Commercial</th>
<th>diagram</th>
<th>type</th>
<th>properties</th>
<th>source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image3" alt="Commercial" /></td>
<td>xs:string</td>
<td>content simple</td>
<td>&lt;xs:element name=&quot;Commercial&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>element B6/B.6.3_Context/Technological</th>
<th>diagram</th>
<th>type</th>
<th>properties</th>
<th>source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image4" alt="Technological" /></td>
<td>xs:string</td>
<td>content simple</td>
<td>&lt;xs:element name=&quot;Technological&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>element B6/B.6.3_Context/Availability_of_resources</th>
<th>diagram</th>
<th>type</th>
<th>properties</th>
<th>source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image5" alt="Availability_of_resources" /></td>
<td>xs:string</td>
<td>content simple</td>
<td>&lt;xs:element name=&quot;Availability_of_resources&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>type</th>
<th>xs:string</th>
</tr>
</thead>
<tbody>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Availability_of_resources&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>

**element B6/B.6.4_Future_changes**

<table>
<thead>
<tr>
<th>diagram</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>properties</td>
<td>content complex</td>
</tr>
<tr>
<td>children</td>
<td>Expansion_and_contraction</td>
</tr>
<tr>
<td>annotation</td>
<td>documentation</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;B.6.4_Future_changes&quot;&gt;</td>
</tr>
<tr>
<td></td>
<td><a href="">xs:documentation</a>Reasons for change should be stated.&lt;/xs:documentation&gt;</td>
</tr>
<tr>
<td></td>
<td><a href="">xs:complexType</a></td>
</tr>
<tr>
<td></td>
<td><a href="">xs:sequence</a></td>
</tr>
<tr>
<td></td>
<td>&lt;xs:element name=&quot;Expansion_and_contraction&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;/xs:sequence&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;/xs:complexType&gt;</td>
</tr>
</tbody>
</table>

**element B6/B.6.4_Future_changes/Expansion_and_contraction**

<table>
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<tr>
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</tr>
<tr>
<td>properties</td>
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</tr>
<tr>
<td>source</td>
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</table>

**complexType B7**

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<thead>
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<tbody>
<tr>
<td>B.7.1_Activities_and_processes...</td>
<td></td>
</tr>
<tr>
<td>B.7.2_Users</td>
<td></td>
</tr>
<tr>
<td>B.7.3_Relationships</td>
<td></td>
</tr>
<tr>
<td>B.7.4_Schedule_of_items_to_be_h...</td>
<td></td>
</tr>
<tr>
<td>The client should provide</td>
<td></td>
</tr>
<tr>
<td>B.7.5_Special_inputs</td>
<td></td>
</tr>
<tr>
<td>B.7.6_By_products</td>
<td></td>
</tr>
<tr>
<td>The opportunity for the</td>
<td></td>
</tr>
<tr>
<td>B.7.7_Safety_and_health_risks</td>
<td></td>
</tr>
<tr>
<td>The opportunity for the recovery of</td>
<td></td>
</tr>
</tbody>
</table>
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Appendix

<table>
<thead>
<tr>
<th>children</th>
<th>element</th>
<th>annotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.7.1_Activities_and_processes_schedule</td>
<td>B.7.2_Users</td>
<td>Briefing_checklist_B/B.7_Intended_occupancy_in_detail</td>
</tr>
<tr>
<td>B.7.4_Schedule_of_items_to_be_housed</td>
<td>B.7.3_Relationships</td>
<td>Documentation</td>
</tr>
<tr>
<td>B.7.6_By_products</td>
<td></td>
<td>Intended occupancy in detail</td>
</tr>
<tr>
<td>B.7.7_Safety_and_health_risks</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

source

```xml
<xs:complexType name="B7">
  <xs:annotation>
    <xs:documentation>Intended occupancy in detail</xs:documentation>
  </xs:annotation>
  <xs:sequence>
    <xs:element name="B.7.1_Activities_and_processes_schedule">
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        <xs:sequence>
          <xs:element name="Nature_and_purpose" type="xs:string"/>
          <xs:element name="Frequency_duration_permanence" type="xs:string"/>
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        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="B.7.2_Users">
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          <xs:element name="Overall_organization" type="xs:string"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="B.7.3_Relationships">
      <xs:complexType>
        <xs:sequence>
          <xs:element name="Similarity_of_activities" type="xs:string"/>
          <xs:element name="Communications_and_transport" type="xs:string"/>
          <xs:element name="People" type="xs:string"/>
          <xs:element name="Information" type="xs:string"/>
          <xs:element name="Organizational_connections" type="xs:string"/>
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      </xs:complexType>
    </xs:element>
    <xs:element name="B.7.4_Schedule_of_items_to_be_housed">
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          <xs:element name="Energy_gas_electricity" type="xs:string"/>
          <xs:element name="Water" type="xs:string"/>
          <xs:element name="Information_technology" type="xs:string"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="B.7.5_Special_inputs">
      <xs:complexType>
        <xs:sequence>
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          <xs:element name="Energy_gas_electricity" type="xs:string"/>
          <xs:element name="Water" type="xs:string"/>
          <xs:element name="Information_technology" type="xs:string"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
  </xs:sequence>
</xs:complexType>
```

The client should provide detailed information about items of specialist equipment, furnishings and plant.

Quantities and capacities should be stated.

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<xs:element name="B.7.6_By_products">
  <xs:annotation>
    <xs:documentation>The opportunity for the recovery of by-products and the necessary precautions should be stated.</xs:documentation>
  </xs:annotation>
  <xs:complexType>
    <xs:sequence>
      <xs:element name="Wast_material" type="xs:string"/>
      <xs:element name="Heat" type="xs:string"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>

<xs:element name="B.7.7_Safety_and_health_risks">
  <xs:annotation>
    <xs:documentation>The opportunity for the recovery of by-products and the necessary precautions should be stated.</xs:documentation>
  </xs:annotation>
  <xs:complexType>
    <xs:sequence>
      <xs:element name="Accident" type="xs:string"/>
      <xs:element name="Stability" type="xs:string"/>
      <xs:element name="Vibration_and_noise" type="xs:string"/>
      <xs:element name="Fire_and_explosions" type="xs:string"/>
      <xs:element name="Contamination" type="xs:string"/>
      <xs:element name="Radiation" type="xs:string"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>

---

**element B7/B.7.1_Activities_and_processes_schedule**

<table>
<thead>
<tr>
<th>diagram</th>
<th>B.7.1_Activities_and_processes_schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>property</td>
<td>content complex</td>
</tr>
<tr>
<td>children</td>
<td>Nature_and_purpose Frequency_duration_permanence Sensivity_to_disruption</td>
</tr>
</tbody>
</table>

*source* <xs:element name="B.7.1_Activities_and_processes_schedule">
  <xs:complexType>
    <xs:sequence>
      <xs:element name="Nature_and_purpose" type="xs:string"/>
      <xs:element name="Frequency_duration_permanence" type="xs:string"/>
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<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
</tr>
</thead>
</table>
| B7/B.7.1_Activities_and_processes_schedule/Nature_and_purpose | **Diagram**: Nature and purpose diagram  
**Type**: xs:string  
**Properties**: Content simple  
**Source**: `<xs:element name="Nature_and_purpose" type="xs:string"/>` |
| B7/B.7.1_Activities_and_processes_schedule/Frequency_duration_permanence | **Diagram**: Frequency duration permanence diagram  
**Type**: xs:string  
**Properties**: Content simple  
**Source**: `<xs:element name="Frequency_duration_permanence" type="xs:string"/>` |
| B7/B.7.1_Activities_and_processes_schedule/Sensivity_to_disruption | **Diagram**: Sensitivity to disruption diagram  
**Type**: xs:string  
**Properties**: Content simple  
**Source**: `<xs:element name="Sensivity_to_disruption" type="xs:string"/>` |
| B7/B.7.2_Users | **Diagram**: B.7.2_Users diagram  
**Properties**: Content complex  
**Children**: Nature_and_numbers, Overall_organization  
**Source**: `<xs:element name="B.7.2_Users">  
<xs:complexType>  
<xs:sequence>  
<xs:element name="Nature_and_numbers" type="xs:string"/>  
<xs:element name="Overall_organization" type="xs:string"/>  
</xs:sequence>  
</xs:complexType>  
</xs:element>` |
| B7/B.7.2_Users/Nature_and_numbers | **Diagram**: Nature_and_numbers diagram |
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Appendix B

<table>
<thead>
<tr>
<th>Element</th>
<th>Diagram</th>
<th>Type</th>
<th>Properties</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>B7/B.7.2_Users/Overall_organization</td>
<td><img src="image1.png" alt="Diagram" /></td>
<td>xs:string</td>
<td>content simple</td>
<td><code>&lt;xs:element name=&quot;Overall_organization&quot; type=&quot;xs:string&quot;/&gt;</code></td>
</tr>
</tbody>
</table>
| B7/B.7.3_Relationships | ![Diagram](image2.png) | xs:string | content complex | `<xs:element name="B.7.3_Relationships" type="xs:string"/>
  <xs:complexType>
    <xs:sequence>
      <xs:element name="Similarity_of_activities" type="xs:string"/>
      <xs:element name="Communications_and_transport" type="xs:string"/>
      <xs:element name="People" type="xs:string"/>
      <xs:element name="Information" type="xs:string"/>
      <xs:element name="Organizational_connections" type="xs:string"/>
    </xs:sequence>
  </xs:complexType>` |
| B7/B.7.3_Relationships/Similarity_of_activities | ![Diagram](image3.png) | xs:string | content simple | `<xs:element name="Similarity_of_activities" type="xs:string"/>` |
element B7/B.7.3_Relationships/Communications_and_transport

<table>
<thead>
<tr>
<th>diagram</th>
<th>Communications_and_transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
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element B7/B.7.3_Relationships/People

<table>
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<tr>
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<th>People</th>
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<tr>
<td>type</td>
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<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td><code>&lt;xs:element name=&quot;People&quot; type=&quot;xs:string&quot;/&gt;</code></td>
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</table>

element B7/B.7.3_Relationships/Information

<table>
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<tr>
<th>diagram</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
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element B7/B.7.3_Relationships/Organizational_connections

<table>
<thead>
<tr>
<th>diagram</th>
<th>Organizational_connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td><code>&lt;xs:element name=&quot;Organizational_connections&quot; type=&quot;xs:string&quot;/&gt;</code></td>
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</tbody>
</table>

element B7/B.7.4_Schedule_of_items_to_be_housed

<table>
<thead>
<tr>
<th>diagram</th>
<th>B.7.4 Schedule_of_items_to_be_housed</th>
</tr>
</thead>
<tbody>
<tr>
<td>The client should provide documentation about items of specialist equipment, furnishings and plant.</td>
<td></td>
</tr>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>annotation</td>
<td>documentation about items of specialist equipment, furnishings and plant.</td>
</tr>
<tr>
<td>source</td>
<td><code>&lt;xs:element name=&quot;B.7.4_Schedule_of_items_to_be_housed&quot; type=&quot;xs:string&quot;&gt;</code> <code>&lt;xs:annotation&gt;</code></td>
</tr>
</tbody>
</table>
The client should provide detailed information about items of specialist equipment, furnishings and plant.

Quantities and capacities should be stated.

- **Raw_materials**
- **Energy_gas_electricity**
- **Water**
- **Information_technology**
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**element B7/B.7.5_Special_inputs/Water**

- **diagram**
  - [Water diagram]
- **type** xs:string
- **properties** content simple
- **source** `<xs:element name="Water" type="xs:string"/>

**element B7/B.7.5_Special_inputs/Information_technology**

- **diagram**
  - [Information_technology diagram]
- **type** xs:string
- **properties** content simple
- **source** `<xs:element name="Information_technology" type="xs:string"/>

**element B7/B.7.6_By_products**

- **diagram**
  - [B.7.6_By_products diagram]
- **properties** content complex
- **children** Wast_material Heat
- **annotation**
  - documentation: The opportunity for the recovery of by-products and the necessary precautions should be stated.
- **source** `<xs:element name="B.7.6_By_products">
    <xs:annotation>
      <xs:documentation>The opportunity for the recovery of by-products and the necessary precautions should be stated.</xs:documentation>
    </xs:annotation>
    <xs:complexType>
      <xs:sequence>
        <xs:element name="Wast_material" type="xs:string"/>
        <xs:element name="Heat"/>
      </xs:sequence>
    </xs:complexType>
  </xs:element>`

**element B7/B.7.6_By_products/Wast_material**

- **diagram**
  - [Wast_material diagram]
- **type** xs:string
- **properties** content simple
- **source** `<xs:element name="Wast_material" type="xs:string"/>"
The opportunity for the recovery of by-products and the necessary precautions should be stated.

```xml
<xs:element name="B.7.7_Safety_and_health_risks">
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        <xs:documentation>The opportunity for the recovery of by-products and the necessary precautions should be stated.</xs:documentation>
    </xs:annotation>
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        <xs:sequence>
            <xs:element name="Accident"/>
            <xs:element name="Stability" type="xs:string"/>
            <xs:element name="Vibration_and_noise" type="xs:string"/>
            <xs:element name="Fire_and_explosions" type="xs:string"/>
            <xs:element name="Contamination" type="xs:string"/>
            <xs:element name="Radiation" type="xs:string"/>
        </xs:sequence>
    </xs:complexType>
</xs:element>
```

```xml
<xs:element name="Accident"/>
```

```xml
<xs:element name="Stability" type="xs:string"/>
```
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Appendix B

<table>
<thead>
<tr>
<th>properties</th>
<th>source</th>
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<tbody>
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**element B7/B.7.7_Safety_and_health_risks/Vibration_and_noise**

<table>
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<th>type</th>
<th>properties</th>
<th>source</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Vibration_and_noise" /></td>
<td><code>xs:string</code></td>
<td>content simple</td>
<td><code>&lt;xs:element name=&quot;Vibration_and_noise&quot; type=&quot;xs:string&quot;/&gt;</code></td>
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**element B7/B.7.7_Safety_and_health_risks/Fire_and_explosions**

<table>
<thead>
<tr>
<th>diagram</th>
<th>type</th>
<th>properties</th>
<th>source</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Fire_and_explosions" /></td>
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<td>content simple</td>
<td><code>&lt;xs:element name=&quot;Fire_and_explosions&quot; type=&quot;xs:string&quot;/&gt;</code></td>
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</table>

**element B7/B.7.7_Safety_and_health_risks/Contamination**

<table>
<thead>
<tr>
<th>diagram</th>
<th>type</th>
<th>properties</th>
<th>source</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Contamination" /></td>
<td><code>xs:string</code></td>
<td>content simple</td>
<td><code>&lt;xs:element name=&quot;Contamination&quot; type=&quot;xs:string&quot;/&gt;</code></td>
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</tbody>
</table>

**element B7/B.7.7_Safety_and_health_risks/Radiation**

<table>
<thead>
<tr>
<th>diagram</th>
<th>type</th>
<th>properties</th>
<th>source</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Radiation" /></td>
<td><code>xs:string</code></td>
<td>content simple</td>
<td><code>&lt;xs:element name=&quot;Radiation&quot; type=&quot;xs:string&quot;/&gt;</code></td>
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</table>
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Appendix B

complexType B8

diagram

children
- B.8.1_Effects_on_the_clients_enterprise
- B.8.2_Effects_on_users_and_the_public
- B.8.3_Effects_on_environment
- B.8.4_Control_of_undesirable_effects
- B.8.5_Priorities

used by
- element: Briefing_checklist_B/B.8_Intendes_effects_of_the_project

annotation
documentation: Intended effects of the project

source
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  <xs:annotation>
    <xs:documentation>Intended effects of the project</xs:documentation>
  </xs:annotation>
  <xs:sequence>
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          <xs:element name="Financial" type="xs:string"/>
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          <xs:element name="Political" type="xs:string"/>
          <xs:element name="Image" type="xs:string"/>
          <xs:element name="Continuity_of_operations" type="xs:string"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="B.8.2_Effects_on_users_and_the_public">
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        <xs:sequence>
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          <xs:element name="Convenience_of_systems" type="xs:string"/>
          <xs:element name="Communications" type="xs:string"/>
          <xs:element name="Security" type="xs:string"/>
          <xs:element name="Maintenance" type="xs:string"/>
          <xs:element name="Escape" type="xs:string"/>
          <xs:element name="Levels_of_beneficial_effects" type="xs:string"/>
          <xs:element name="Comfort" type="xs:string"/>
          <xs:element name="Cleanliness" type="xs:string"/>
          <xs:element name="Health" type="xs:string"/>
          <xs:element name="Safety" type="xs:string"/>
          <xs:element name="Aesthetic" type="xs:string"/>
          <xs:element name="Appearance" type="xs:string"/>
          <xs:element name="Atmosphere" type="xs:string"/>
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      </xs:complexType>
    </xs:element>
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</xs:complexType>
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Appendix B

<table>
<thead>
<tr>
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<tbody>
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<td>&lt;xs:element name=&quot;B.8.3_Effects_on_environment&quot;&gt;</td>
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<tr>
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</tr>
<tr>
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</tr>
<tr>
<td>&lt;/xs:sequence&gt;</td>
</tr>
<tr>
<td>&lt;/xs:complexType&gt;</td>
</tr>
<tr>
<td>&lt;/xs:element&gt;</td>
</tr>
<tr>
<td>&lt;xs:element name=&quot;B.8.4_Control_of_undesirable_effects&quot;&gt;</td>
</tr>
<tr>
<td><a href="">xs:annotation</a></td>
</tr>
<tr>
<td><a href="">xs:documentation</a>The extent to which undesirable effects must be reduced by the design should be stated.&lt;/xs:documentation&gt;</td>
</tr>
<tr>
<td>&lt;/xs:annotation&gt;</td>
</tr>
<tr>
<td><a href="">xs:complexType</a></td>
</tr>
<tr>
<td><a href="">xs:sequence</a></td>
</tr>
<tr>
<td>&lt;xs:element name=&quot;Distrurbances&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
<tr>
<td>&lt;xs:element name=&quot;Nuisances&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
<tr>
<td>&lt;xs:element name=&quot;Pollution&quot;/&gt;</td>
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</tr>
<tr>
<td>&lt;/xs:complexType&gt;</td>
</tr>
<tr>
<td>&lt;/xs:element&gt;</td>
</tr>
<tr>
<td>&lt;xs:element name=&quot;B.8.5_Priorities&quot;&gt;</td>
</tr>
<tr>
<td><a href="">xs:annotation</a></td>
</tr>
<tr>
<td><a href="">xs:documentation</a>Conflicts may arise, for example between image and security or among the interests of the client, user and the public, or on matters of cost, time and quality. Hence there is a need to consider here the overall project priorities as distinct from those under individual sections. In some cases, it may be difficult or even impossible to agree on these in the early stages without having a design proposal to hand. However, stating the conflicts explicitly helps to make the designer aware and helps to resolve the issues.&lt;/xs:documentation&gt;</td>
</tr>
<tr>
<td>&lt;/xs:annotation&gt;</td>
</tr>
<tr>
<td><a href="">xs:complexType</a></td>
</tr>
<tr>
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</tr>
<tr>
<td>&lt;xs:element name=&quot;Time&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
<tr>
<td>&lt;xs:element name=&quot;Cost&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
<tr>
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</tr>
<tr>
<td>&lt;/xs:sequence&gt;</td>
</tr>
<tr>
<td>&lt;/xs:complexType&gt;</td>
</tr>
<tr>
<td>&lt;/xs:element&gt;</td>
</tr>
</tbody>
</table>
element B8/B.8.1_Effects_on_the_clients企業

Diagram

```
<xs:element name="B.8.1_Effects_on_the_clients.enterprise">
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        <xs:sequence>
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            <xs:element name="Financial" type="xs:string"/>
            <xs:element name="Social" type="xs:string"/>
            <xs:element name="Cultural" type="xs:string"/>
            <xs:element name="Political" type="xs:string"/>
            <xs:element name="Image" type="xs:string"/>
            <xs:element name="Continuity_of_operations" type="xs:string"/>
        </xs:sequence>
    </xs:complexType>
</xs:element>
```

properties: content complex


source:
```
<xs:element name="B.8.1_Effects_on_the_clients.enterprise">
    <xs:complexType>
        <xs:sequence>
            <xs:element name="Economical" type="xs:string"/>
            <xs:element name="Financial" type="xs:string"/>
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            <xs:element name="Political" type="xs:string"/>
            <xs:element name="Image" type="xs:string"/>
            <xs:element name="Continuity_of_operations" type="xs:string"/>
        </xs:sequence>
    </xs:complexType>
</xs:element>
```

element B8/B.8.1_Effects_on_the_clients.enterprise/Economical

Diagram

```
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```

properties: xs:string

source:
```
<xs:element name="Economical" type="xs:string"/>
```

element B8/B.8.1_Effects_on_the_clients.enterprise/Financial

Diagram

```
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```

properties: xs:string

source:
```
<xs:element name="Financial" type="xs:string"/>
```

element B8/B.8.1_Effects_on_the_clients.enterprise/Social

Diagram

```
<xs:element name="Social" type="xs:string"/>
```

properties: xs:string

source:
```
<xs:element name="Social" type="xs:string"/>
```
Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

**Appendix B**

---

**element B8/B.8.1_Effects_on_the_clients_enterprise/Cultural**

```
<xs:element name="Cultural" type="xs:string"/>
```

---

**element B8/B.8.1_Effects_on_the_clients_enterprise/Political**

```
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```

---

**element B8/B.8.1_Effects_on_the_clients_enterprise/Image**

```
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```

---

**element B8/B.8.1_Effects_on_the_clients_enterprise/Continuity_of_operations**

```
<xs:element name="Continuity_of_operations" type="xs:string"/>
```
element B8/B.8.2_Effects_on_users_and_the_public

```
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    <xs:sequence>
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      <xs:element name="Convenience_of_systems" type="xs:string"/>
      <xs:element name="Communications" type="xs:string"/>
      <xs:element name="Security" type="xs:string"/>
      <xs:element name="Maintenance" type="xs:string"/>
      <xs:element name="Escape" type="xs:string"/>
      <xs:element name="Levels_of_beneficial_effects" type="xs:string"/>
      <xs:element name="Comfort" type="xs:string"/>
      <xs:element name="Cleanliness" type="xs:string"/>
      <xs:element name="Health" type="xs:string"/>
      <xs:element name="Safety" type="xs:string"/>
      <xs:element name="Aesthetic" type="xs:string"/>
      <xs:element name="Appearance" type="xs:string"/>
      <xs:element name="Atmosphere" type="xs:string"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
```

element B8/B.8.2_Effects_on_users_and_the_public/Convenience_of_spaces

```
<xs:element name="Convenience_of_spaces" type="xs:string"/>
```
Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

Appendix B

Ph.D. thesis
CHRISTIAN BAIER
298
### Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

#### Appendix B

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>B8/B.8.2_Effects_on_users_and_the_public/Levels_of_beneficial_effects</strong></td>
<td></td>
</tr>
</tbody>
</table>

#### Properties:
- **Diagram**: 
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- **Type**: `xs:string`
- **Properties**: `content simple`
- **Source**: `<xs:element name="Levels_of_beneficial_effects" type="xs:string"/>

| **B8/B.8.2_Effects_on_users_and_the_public/Comfort** | 

#### Properties:
- **Diagram**: 
  - `<Comfort>`
- **Type**: `xs:string`
- **Properties**: `content simple`
- **Source**: `<xs:element name="Comfort" type="xs:string"/>

| **B8/B.8.2_Effects_on_users_and_the_public/Cleanliness** | 

#### Properties:
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  - `<Cleanliness>`
- **Type**: `xs:string`
- **Properties**: `content simple`
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| **B8/B.8.2_Effects_on_users_and_the_public/Health** | 

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| **B8/B.8.2_Effects_on_users_and_the_public/Safety** | 

#### Properties:
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- **Properties**: `content simple`
- **Source**: `<xs:element name="Safety" type="xs:string"/>"
element B8/B.8.2_Effects_on_users_and_the_public/Aesthetic

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<th>Appearance</th>
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element B8/B.8.2_Effects_on_users_and_the_public/Atmosphere

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<tr>
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<td>xs:string</td>
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element B8/B.8.3_Effects_on_environment

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<tr>
<th>diagram</th>
<th>B.8.3_Effects_on_environment Ecology</th>
</tr>
</thead>
<tbody>
<tr>
<td>properties</td>
<td>content complex</td>
</tr>
<tr>
<td>children</td>
<td>Ecology</td>
</tr>
</tbody>
</table>
| source | <xs:element name="B.8.3_Effects_on_environment">  
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  <xs:sequence>  
  <xs:element name="Ecology" type="xs:string"/>  
  </xs:sequence>  
  </xs:complexType>  
  </xs:element> |

element B8/B.8.3_Effects_on_environment/Ecology

<table>
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<th>Ecology</th>
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</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
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<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Ecology&quot; type=&quot;xs:string&quot;/&gt;</td>
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</table>
The extent to which undesirable effects must be reduced by the design should be stated.

```xml
<xs:element name="B.8.4_Control_of_undesirable_effects">
  <xs:annotation>
    <xs:documentation>The extent to which undesirable effects must be reduced by the design should be stated.</xs:documentation>
  </xs:annotation>
  <xs:complexType>
    <xs:sequence>
      <xs:element name="Distrurbances" type="xs:string"/>
      <xs:element name="Nuisances" type="xs:string"/>
      <xs:element name="Pollution"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
```

**Element B8/B.8.4_Control_of_undesirable_effects/Distrurbances**

- **Diagram**: 
- **Type**: xs:string
- **Properties**: content simple
- **Source**: 

```xml
<xs:element name="Distrurbances" type="xs:string"/>
```

**Element B8/B.8.4_Control_of_undesirable_effects/Nuisances**

- **Diagram**: 
- **Type**: xs:string
- **Properties**: content simple
- **Source**: 

```xml
<xs:element name="Nuisances" type="xs:string"/>
```

**Element B8/B.8.4_Control_of_undesirable_effects/Pollution**

- **Diagram**: 
- **Source**: 

```xml
<xs:element name="Pollution"/>
```
Conflicts may arise, for example between image and security or among the interests of the client, user and the public, or on matters of cost, time and quality. Hence there is a need to consider here the overall project priorities as distinct from those under individual sections. In some cases, it may be difficult or even impossible to agree on these in the early stages without having a design proposal to hand. However, stating the conflicts explicitly helps to make the designer aware and helps to resolve the issues.

```xml
<xs:element name="B.8.5_Priorities">
  <xs:annotation>
    <xs:documentation>
      Conflicts may arise, for example between image and security or among the interests of the client, user and the public, or on matters of cost, time and quality. Hence there is a need to consider here the overall project priorities as distinct from those under individual sections. In some cases, it may be difficult or even impossible to agree on these in the early stages without having a design proposal to hand. However, stating the conflicts explicitly helps to make the designer aware and helps to resolve the issues.
    </xs:documentation>
  </xs:annotation>
  <xs:complexType>
    <xs:sequence>
      <xs:element name="Value_for_money" type="xs:string"/>
      <xs:element name="Time" type="xs:string"/>
      <xs:element name="Cost" type="xs:string"/>
      <xs:element name="Quality" type="xs:string"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
```

```xml
<xs:element name="Value_for_money" type="xs:string"/>
```
Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

Appendix B

element B8/B.8.5_Priorities/Time

diagram

<table>
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<tbody>
<tr>
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<td>content simple</td>
</tr>
</tbody>
</table>

source

<xs:element name="Time" type="xs:string"/>

element B8/B.8.5_Priorities/Cost

diagram

<table>
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<th>xs:string</th>
</tr>
</thead>
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source

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element B8/B.8.5_Priorities/Quality

diagram

<table>
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source

<xs:element name="Quality" type="xs:string"/>

complexType Briefing_checklist_A

diagram

children

A.1_Identity_of_the_project
A.2_Purpose_of_the_project
A.3_Scope_of_the_project
A.4_Identity_of_participants
A.5_Identity_of_other_related_groups

used by

element Briefing_Checklists/Briefing_checklist_A

annotation
documentation Briefing checklist A

source
<xs:complexType name="Briefing_checklist_A">
<xs:annotation>...</xs:annotation>
</xs:complexType>
Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

Appendix B

Briefing checklist A

<table>
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<th>content</th>
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<td>A.1_Identity_of_the_project</td>
<td>A1</td>
<td>complex</td>
</tr>
</tbody>
</table>

A1

- A.1.1_Project
- A.1.2_Name
- A.1.3_Title
- A.1.4_Reference_number
- A.1.5_Location
- A.1.6_Aдрес
- A.1.7_Building_category
- A.1.8_Type_of_use
This section should express the client’s needs in the broadest terms. The Statements are expanded in B.3 and B.6.
element Briefing_checklist_A/A.4_Identity_of_participants

In order to facilitate initial contacts, names, addresses, telephone numbers, telex and facsimile (fax) numbers should be provided for all organizations and individuals likely to participate in the project. The name of any official representative of an organization should also be given here. Further detailed information is provided in B.1.
In order to facilitate initial contacts, names, addresses, telephone numbers, telex and facsimile(fax) numbers should be provided for all organizations and individuals likely to participate in the project. The name of any official representative of an organization should also be given here. Further detailed information is provided in B.1.

In addition to the participants and those paid by the client to carry out the project, there will be related groups concerned with some aspects of the project. It is important that the participants should have information about the roles and organization of such bodies.
complexType Briefing_checklist_B

children

B.1 Project_management
B.2 Laws_standards_and_codes
B.3 Financial_and_time_constraints
B.4 Background_and_historical_influences
B.5 Influences_of_site_and_surroundings
B.6 Clients_future.enterprise
B.7 Intended_occupancy_in_detail
B.8 Intended_effects_of_the_project

used by

element Briefing_Checklists/Briefing_checklist_B

annotation documentation
Briefing checklist B

source
<xs:complexType name="Briefing_checklist_B">
  <xs:annotation>
    <xs:documentation>Briefing checklist B</xs:documentation>
  </xs:annotation>
  <xs:sequence>
    <xs:element name="B.1_Project_management" type="B1">
      <xs:annotation>
        <xs:documentation>For each participant authority, responsibility, roles and skills should be stated, organizational diagrams prepared and relationships defined. The procedure and time scale for the selection of consultants not yet appointed should be stated. See also B.1.4. The organizational framework is to be given some priority because certain
      </xs:annotation>
    </xs:element>
    <xs:element name="B.2_Laws_standards_and_codes">
      <xs:annotation>
        <xs:documentation>For convenience, all laws, regulations,
      </xs:annotation>
    </xs:element>
    <xs:element name="B.3_Financial_and_time_constraints">
      <xs:annotation>
        <xs:documentation>The section allows participants to be aware of the detailed matters which may have influenced the
      </xs:annotation>
    </xs:element>
    <xs:element name="B.4_Background_and_historical_influences">
      <xs:annotation>
        <xs:documentation>This section will provide the basis for preliminary studies prior to the selection of a site/building or for assessing the suitability of an existing site/building owned by the client.
      </xs:annotation>
    </xs:element>
    <xs:element name="B.5_Influences_of_site_and_surroundings">
      <xs:annotation>
        <xs:documentation>This section allows participants to be aware of the detailed matters which may have influenced the
      </xs:annotation>
    </xs:element>
    <xs:element name="B.6_Clients_future.enterprise">
      <xs:annotation>
        <xs:documentation>This section is intended to record information/decisions concerning the client's
      </xs:annotation>
    </xs:element>
    <xs:element name="B.7_Intended_occupancy_in_detail">
      <xs:annotation>
        <xs:documentation>In this section the activities of the future client and user occupancy are given a more detailed
      </xs:annotation>
    </xs:element>
    <xs:element name="B.8_Intended_effects_of_the_project">
      <xs:annotation>
        <xs:documentation>The section concerns quality and strategic matters of project priorities and value for money. Ultimately the building project will be judged in terms of the effects it produces on the client's enterprise, the occupancy and the public. Therefore the statement of the required effects that any future building is required to have must
      </xs:annotation>
    </xs:element>
  </xs:sequence>
</xs:complexType>
The procedure and timescale for the selection of consultants not yet appointed should be stated. See also B.3.4.

The organizational framework is to be given some priority because certain parts of it must be clearly established before later parts of the brief can be considered.

The overall management of the project in its initial stages is vital in order to achieve the comprehensive and authoritative definition of the needs and aims of the client. This task is essential for good communications, for motivation, coordination and for effective control of time, cost and quality.

Overall management is the responsibility of the client and should only be delegated for exceptional reasons and then only with great care.

For convenience, all laws, regulations, standards, codes and other relevant external influences are all grouped under this heading whether they concern the site, occupancy, environment or other aspect of the project.

This section allows participants to be aware of the detailed matters which may have influenced the purpose of the project set out in A.2. For comparison, the details of the client's intended future enterprise, the intended occupancy and the intended effects of the project are to be given in B.6 to B.8.

Future changes which may affect the matters listed in this section are likely to be outside the control of the client.

Each matter should be considered in relation to both the site and the surroundings.

This section is intended to record information/decisions concerning the client's future activity. The activities of the client are what is intended to be done in contrast to the next section on intended occupancy which addresses how these activities are performed.
element Briefing_checklist_B/B.1_Project_management

diagram

B.1_Project_management

For each participant authority, responsibility, roles and skills should be stated, organizational diagrams prepared and relationships defined.
The procedure and timeline for the selection of consultants not yet appointed should be stated. See also B.3.4.
The organizational framework is to be given some priority because certain

<table>
<thead>
<tr>
<th>type</th>
<th>B1</th>
</tr>
</thead>
<tbody>
<tr>
<td>properties</td>
<td>content complex</td>
</tr>
<tr>
<td>children</td>
<td>B.1.1_Participants B.1.2_Related_groups_organization B.1.3_Design_evaluation_procedures B.1.4_Quality_control</td>
</tr>
<tr>
<td>annotation</td>
<td>documentation For each participant authority, responsibility, roles and skills should be stated, organizational diagrams prepared and relationships defined.</td>
</tr>
</tbody>
</table>
The procedure and timescale for the selection of consultants not yet appointed should be stated. See also B.3.4.

The organizational framework is to be given some priority because certain parts of it must be clearly established before later parts of the brief can be considered.

The overall management of the project in its initial stages is vital in order to achieve the comprehensive and authoritative definition of the needs and aims of the client. This task is essential for good communications, for motivation, coordination and for effective control of time, cost and quality.

Overall management is the responsibility of the client and should only be delegated for exceptional reasons and then only with great care.

For each participant authority, responsibility, roles and skills should be stated, organizational diagrams prepared and relationships defined.

The procedure and timescale for the selection of consultants not yet appointed should be stated. See also B.3.4.

The organizational framework is to be given some priority because certain parts of it must be clearly established before later parts of the brief can be considered.

The overall management of the project in its initial stages is vital in order to achieve the comprehensive and authoritative definition of the needs and aims of the client. This task is essential for good communications, for motivation, coordination and for effective control of time, cost and quality.

Overall management is the responsibility of the client and should only be delegated for exceptional reasons and then only with great care.
For convenience, all laws, regulations, standards, codes and other relevant external influences are all grouped under this heading whether they concern the site, occupancy, environment or other aspect of the project.

Schema:

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<xs:element name="B.2_Laws_standards_and_codes" type="B2">
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    <xs:documentation>For convenience, all laws, regulations, standards, codes and other relevant external influences are all grouped under this heading whether they concern the site, occupancy, environment or other aspect of the project.</xs:documentation>
  </xs:annotation>
</xs:element>
```

**Briefing_checklist_B/B.3_Financial_and_time_constraints**

**Diagram:**

```
B.3_Financial_and_time_constraints

```

**Properties:**

- **Type:** B3
- **Content:** complex
- **Children:**
  - B.3.1_Financing_the_project
  - B.3.2_Budgets
  - B.3.3_Costs_in_use
  - B.3.4_Target_dates
  - B.3.5_Life_expectancy
  - B.3.6_Financial_and_time_risk

**Source:**

```xml
<xs:element name="B.3_Financial_and_time_constraints" type="B3"/>
```

**Briefing_checklist_B/B.4_Background_and_historical_influences**

**Diagram:**

```
B.4_Background_and_historical_influences

```

**Properties:**

- **Type:** B4
- **Content:** complex
- **Children:**
  - B.4.1_Project_history
  - B.4.2_Current_situation
  - B.4.3_Reason_for_current_action
  - Commitments

**Source:**

```xml
<xs:element name="B.4_Background_and_historical_influences" type="B4"/>
```
This section allows participants to be aware of the detailed matters which may have influenced the purpose of the project set out in A.2. For comparison, the details of the client's intended future enterprise, the intended occupancy and the intended effects of the project are to be given in B.6 to B.8.

This section will provide the basis for preliminary studies prior to the selection of a site/building or for assessing the suitability of an existing site/building owned by the client. Future changes which may affect the matters listed in this section are likely to be outside the control of the client. Each matter should be considered in relation to both the site and the surroundings.
element Briefing_checklist_B/B.6_Clients_future_enterprise

diagram

<table>
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<th>B.6_Clients_future_enterprise</th>
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<tbody>
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<td>B6</td>
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</tbody>
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**type**: B6  
**properties**: content: complex  
**children**: B.6.1_Purpose, B.6.2_Size, B.6.3_Context, B.6.4_Future_changes

**annotation**

This section is intended to record information/decisions concerning the client’s future activity. The activities of the client are what is intended to be done in contrast to the next section on intended occupancy which addresses how these activities are performed.

**source**

```xml
<xs:element name="B.6_Clients_future_enterprise" type="B6">
  <xs:annotation>
    <xs:documentation>This section is intended to record information/decisions concerning the client's future activity. The activities of the client are what is intended to be done in contrast to the next section on intended occupancy which addresses how these activities are performed.</xs:documentation>
  </xs:annotation>
</xs:element>
```

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element Briefing_checklist_B/B.7_Intended_occupancy_in_detail

diagram

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<tbody>
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**type**: B7  
**properties**: content: complex  
**children**: B.7.1_Activities_and_processes_schedule, B.7.2_Users, B.7.3_Relationships, B.7.4_Schedule_of_items_to_be_housed, B.7.5_Special_inputs, B.7.6_By_products, B.7.7_Safety_and_health_risks

**annotation**

In this section the activities of the future client and user occupancy are given a more detailed analysis by describing the individual activities to be performed and the necessary equipment which
needs to be housed. The information begins to form the link between the client’s future enterprise (see B.6) and subsequent design and performance requirements in annex C. Information under this heading should not, however, specify design requirements as this may unnecessarily restrict design options.

**element Briefing_checklist_B/B.8_Intended_effects_of_the_project**

**diagram**

- **type** B8
- **properties** content complex
- **children**
  - B.8.1 Effects on the clients enterprise
  - B.8.2 Effects on users and the public
  - B.8.3 Effects on environment
  - B.8.4 Control of undesirable effects
  - B.8.5 Priorities

**annotatio**

This section concerns quality and strategic matters of project priorities and value for money. Ultimately the building project will be judged in terms of the effects it produces on the client's enterprise, the occupancy and the public. Therefore the statement of the required effects that any future building is required to have must constitute the aims of the project. When specifying the intended effects, the degrees of precision appropriate or possible will vary from item to item. The general nature of the effects may make specification difficult in some cases, particularly as many of the desired levels of required effects (or acceptable limits of adverse effects) can only be stated in qualitative, non-technical terms. Nevertheless, every effort should be made to be explicit as this will help the designer to understand client and user expectations and thus help to avoid abortive work, frustration, delay and disappointment with the final result.
required effects (or acceptable limits of adverse effects) can only be stated in qualitative, non-technical terms. Nevertheless, every effort should be made to be explicit as this will help the designer to understand client and user expectations and thus help to avoid abortive work, frustration, delay and disappointment with the final result.

complexType Briefing_checklist_C

source `<xs:complexType name="Briefing_checklist_C">`

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`<xs:documentation>Briefing checklist C</xs:documentation>`
`</xs:annotation>`
`<xs:sequence>`
`<xs:element name="C.1_Sites_and_surroundings" type="C1">`
`<xs:annotation>`
`<xs:documentation>Most projects involve work outside the site boundaries and this may be extensive and vital in undeveloped areas. This section will start to resolve any conflicts revealed in B.5 and further assist in selecting a suitable site.</xs:documentation>`
`</xs:annotation>`
`</xs:element>`
`<xs:element name="C.2_The_building_as_a_whole" type="C2">`
`<xs:annotation>`
`<xs:documentation>Decisions generally applicable to the building as a whole should be made first, leaving exceptions which call for local variation to be considered and dealt with later. This section can usefully answer the requirements listed in B.8</xs:documentation>`
`</xs:annotation>`
`</xs:element>`
`<xs:element name="C.3_Building_fabric_performance" type="C3">`

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This subsection uses the headings from ISO 6241:1984, table 3. Reference to that International Standard will provide further examples of the components and assemblies included under each heading. Other authoritative lists exist and may be substituted for this list if more appropriate. More detailed performance advice will be available on aspects of the building fabric by referring to the documents listed in annex D.

Most projects involve work outside the site boundaries and this may be extensive and vital in undeveloped areas. This section will start to resolve any conflicts revealed in B.5 and further assist in selecting a suitable site.
This section will start to resolve any conflicts revealed in B.5 and further assist in selecting a suitable site.

Decisions generally applicable to the building as a whole should be made first, leaving exceptions which call for local variation to be considered and dealt with later. This section can usefully answer the requirements listed in B.8.

Decisions generally applicable to the building as a whole should be made first, leaving exceptions which call for local variation to be considered and dealt with later. This section can usefully answer the requirements listed in B.8.
This subsection uses the headings from ISO 6241:1984, table 3. Reference to that International Standard will provide further examples of the components and assemblies included under each heading. Other authoritative lists exist and may be substituted for this list if more appropriate. More detailed performance advice will be available on aspects of the building fabric by referring to the documents listed in annex D.

**element** Briefing_checklist_C/C.4_Grouping_of_spaces

<table>
<thead>
<tr>
<th>diagram</th>
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<tr>
<td>properties</td>
<td>content complex</td>
</tr>
<tr>
<td>children</td>
<td>C.4.1_Zoning C.4.2_Spatial_relationships C.4.3_Physical_characteristics</td>
</tr>
</tbody>
</table>

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**element** Briefing_checklist_C/C.5_Spaces_in_detail

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</thead>
<tbody>
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<td>C5</td>
</tr>
<tr>
<td>properties</td>
<td>content complex</td>
</tr>
<tr>
<td>children</td>
<td>C.5.1_Physical_characteristics C.5.2_Related_activities C.5.3_Relationship_to_other_spaces C.5.4_Building_services</td>
</tr>
</tbody>
</table>

**source** <xs:element name="C.5_Spaces_in_detail" type="C5"/>
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Appendix B

element Briefing_checklist_C.C.6_Plant_equipment_and_furnishings

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>C.6_Plant_equipment_and_furnishings</td>
</tr>
</tbody>
</table>

| type | C6 |
| properties | content, complex |
| children | C.6.1_Items_listed_by_category, C.6.2_Location_and_area_of_use, C.6.3_Installation, C.6.4_Appearance, C.6.5_Maintenance |
| annotation | This subsection should schedule all the required items not fully specified by the client under B.7.4. |
| source | <xs:element name="C.6_Plant_equipment_and_furnishings" type="C6">  
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<xs:documentation>This subsection should schedule all the required items not fully specified by the client under B.7.4.</xs:documentation>  
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complexType Briefing_Checklists

<table>
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<th>diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Briefing_Checklists</td>
</tr>
</tbody>
</table>

| children | Briefing_checklist_A, Briefing_checklist_B, Briefing_checklist_C |
| used by | element ISO9699 |
| annotation | documentation: Checklists A, B, C |
| source | <xs:complexType name="Briefing_Checklists">  
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<xs:documentation>Checklists A, B, C</xs:documentation>  
</xs:annotation>  
<xs:sequence>  
<xs:element name="Briefing_checklist_A" type="Briefing_checklist_A">  
</xs:sequence>  
</xs:complexType> |
Annex A represents a preliminary stage in the preparation of the brief and is intended to establish a very general outline of the type of project and those people likely to participate. By concentrating on the context, aims and resources of the client and users, annex B should provide an understanding for the design team which will result in collective decisions which make full use of the available resources to achieve the aims within the context. The data should not be expressed in terms of design requirements. Annex C is reserved for such information. This annex transforms the content of the previous annexes into individual design decisions on the physical aspects of the site and building(s). Decisions in annex C should not be confused with the design process as they are made individually and in isolation, whereas the subsequent process of designing involves the understanding of the totality simultaneously with its parts and forms the latter into an indivisible whole. These individual decisions may be left to the designer, but even the inexperienced client may have ideas about the design means of meeting his requirements. As far as possible, the decisions in annex C should be stated in performance terms. The decisions should take account of relevant matters such as cost of energy and materials, technical and organizational matters, site constraints, forms of construction, and the adaptability and durability of the design.
Annex A represents a preliminary stage in the preparation of the brief and is intended to establish a very general outline of the type of project and those people likely to participate.

```xml
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  </xs:annotation>
</xs:element>
```
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Appendix B

element Briefing_Checklists/Briefing_checklist_B

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<table>
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</tr>
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<tr>
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<td>B.1 Project_management B.2 Laws_standards_and_codes B.3 Financial_and_time_constraints B.4 Background_and_historical_influences B.5 Influences_of_site_and_surroundings B.6 Clients_future_enterprise B.7 Intended_occupancy_in_detail B.8 Intended_effects_of_the_project</td>
</tr>
<tr>
<td>annotation</td>
<td>By concentrating on the context, aims and resources of the client and users, annex B should provide an understanding for the design team which will result in collective decisions which make full use of the available resources to achieve the aims within the context. The data should not be expressed in terms of design requirements. Annex C is reserved for such information.</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Briefing_checklist_B&quot; type=&quot;Briefing_checklist_B&quot;&gt; <a href="">xs:annotation</a>By concentrating on the context, aims and resources of the client and users, annex B should provide an understanding for the design team which will result in collective decisions which make full use of the available resources to achieve the aims within the context. The data should not be expressed in terms of design requirements. Annex C is reserved for such information. &lt;/xs:annotation&gt;</td>
</tr>
</tbody>
</table>
make full use of the available resources to achieve the aims within the context. The data should not be expressed in terms of design requirements. Annex C is reserved for such information.

This annex transforms the content of the previous annexes into individual design decisions on the physical aspects of the site and building(s). Decisions in annex C should not be confused with the design process as they are made individually and in isolation, whereas the subsequent process of designing involves the understanding of the totality simultaneously with its parts and forms the latter into an indivisible whole. These individual decisions may be left to the designer, but even the inexperienced client may have ideas about the design means of meeting his requirements. As far as possible, the decisions in annex C should be stated in performance terms. The decisions should take account of relevant matters such as cost of energy and materials, technical and organizational matters, site constraints, forms of construction, and the adaptability and durability of the design.
client may have ideas about the design means of meeting his requirements. As far as possible, the decisions in annex C should be stated in performance terms. The decisions should take account of relevant matters such as cost of energy and materials, technical and organizational matters, site constraints, forms of construction, and the adaptability and durability of the design. 

complexType C1

C.1.1_Special_relationships
C.1.2_Protection
C.1.3_Access
C.1.4_Security
C.1.5_Site_zoning
C.1.6_Environmental_control
C.1.7_Utilities
C.1.8_Waste_disposal
C.1.9_Maintance

The need for and the capacity and method of

C.1.8_Waste_disposal

The need for and the capacity and method of

Briefing_checklist_C/C.1_Sites_and_surroundings

Sittes and surroundings

C.1.1_Special_relationships C.1.2_Protection C.1.3_Access C.1.4_Security C.1.5_Site_zoning C.1.6_Environmental_control C.1.7_Utilities C.1.8_Waste_disposal C.1.9_Maintance

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For each category of access, the special needs of visitors, handicapped persons, users and employees should be considered and resolved.

The need for and the capacity and method of distribution should be stated for each utility service, together with any necessary emergency supply in the event of failure.
distribution should be stated for each utility service, together with any necessary emergency supply in the event of failure.

```xml
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<xs:documentation></xs:documentation>
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```

**Diagram: C1/C.1.1_Special_relationships**

```
  C1.1_Special_relationships
   └── Surroundings
       └── Other_buildings
           └── Other_site_features
```

**Element: C1/C.1.1_Special_relationships/Surroundings**

```
<xs:element name="Surroundings" type="xs:string"/>
```

**Element: C1/C.1.1_Special_relationships/Other_buildings**

```
<xs:element name="Other_buildings" type="xs:string"/>
```

**Element: C1/C.1.1_Special_relationships/Other_site_features**

```
<xs:element name="Other_site_features" type="xs:string"/>
```
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Appendix B

<table>
<thead>
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<tbody>
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<td>properties</td>
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```

**element C1/C.1.2_Protection/Flooding**

```xml
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```

**element C1/C.1.2_Protection/Weather**

```xml
<xs:element name="Weather" type="xs:string"/>
```

**element C1/C.1.2_Protection/Erosion**

```xml
<xs:element name="Erosion" type="xs:string"/>
```
Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

Appendix B

**source**

```xml
<xs:element name="Erosion" type="xs:string"/>
```

**element C1/C.1.3_Access**

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<tr>
<th>properties</th>
<th>content</th>
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**children**

- Pedestrians
- Bicycles
- Vehicles
- Emergency_vehicles
- Goods_vehicles
- Public_transport
- Trains
- Busses
- Aircraft
- Waterborne
- Parking
- Road_layouts

**annotation documentation**

For each category of access, the special needs of visitors, handicapped persons, users and employees should be considered and resolved.

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<tr>
<td>properties</td>
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</tr>
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element C1/C.1.3_Access/Trains

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<th>Trains</th>
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</thead>
<tbody>
<tr>
<td>type</td>
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<tr>
<td>properties</td>
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element C1/C.1.3_Access/Busses

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<th>Busses</th>
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<th>Aircraft</th>
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element C1/C.1.3_Access/Waterborne

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</table>
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Appendix B

### element C1/C.1.6_Environmental_control/Wind_shelter

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### element C1/C.1.6_Environmental_control/Planting

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<tbody>
<tr>
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### element C1/C.1.6_Environmental_control/Recontouring

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### element C1/C.1.6_Environmental_control/Works_of_art

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<th>diagram</th>
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<tr>
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### element C1/C.1.6_Environmental_control/Signposting

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<tr>
<th>diagram</th>
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</thead>
<tbody>
<tr>
<td>source</td>
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### element C1/C.1.6_Environmental_control/Furniture

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The need for and the capacity and method of distribution should be stated for each utility service, together with any necessary emergency supply in the event of failure.

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```
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  <xs:complexType>
    <xs:sequence>
      <xs:element name="Source_and_distribution" type="xs:string"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
```
element **C1/C.1.9_Maintance**

<table>
<thead>
<tr>
<th>Diagram</th>
<th>C.1.9_Maintance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>xs:string</td>
</tr>
<tr>
<td>Properties</td>
<td>content simple</td>
</tr>
<tr>
<td>Source</td>
<td><code>&lt;xs:element name=&quot;C.1.9_Maintance&quot; type=&quot;xs:string&quot;/&gt;</code></td>
</tr>
</tbody>
</table>

complexType **C1_road_layouts**

<table>
<thead>
<tr>
<th>Diagram</th>
<th>C1_road_layouts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children</td>
<td>Transit Traffic-calmed Accidents</td>
</tr>
<tr>
<td>Used by</td>
<td>C1/C.1.3_Access/Road_layouts</td>
</tr>
<tr>
<td>Annotation</td>
<td>documentation Definition of road layouts</td>
</tr>
<tr>
<td>Source</td>
<td><code>&lt;xs:complexType name=&quot;C1_road_layouts&quot;&gt;</code></td>
</tr>
<tr>
<td></td>
<td><code>&lt;xs:annotation&gt;</code></td>
</tr>
<tr>
<td></td>
<td><code>&lt;xs:documentation&gt;Definition of road layouts&lt;/xs:documentation&gt;</code></td>
</tr>
<tr>
<td></td>
<td><code>&lt;xs:annotation&gt;</code></td>
</tr>
<tr>
<td></td>
<td><code>&lt;xs:sequence&gt;</code></td>
</tr>
<tr>
<td></td>
<td><code>&lt;xs:element name=&quot;Transit&quot; type=&quot;xs:string&quot;/&gt;</code></td>
</tr>
<tr>
<td></td>
<td><code>&lt;xs:element name=&quot;Traffic-calmed&quot; type=&quot;xs:string&quot;/&gt;</code></td>
</tr>
<tr>
<td></td>
<td><code>&lt;xs:element name=&quot;Accidents&quot; type=&quot;xs:string&quot;/&gt;</code></td>
</tr>
<tr>
<td></td>
<td><code>&lt;xs:sequence&gt;</code></td>
</tr>
<tr>
<td></td>
<td><code>&lt;xs:complexType&gt;</code></td>
</tr>
</tbody>
</table>

element **C1_road_layouts/Transit**

<table>
<thead>
<tr>
<th>Diagram</th>
<th>Transit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>xs:string</td>
</tr>
<tr>
<td>Properties</td>
<td>content simple</td>
</tr>
<tr>
<td>Source</td>
<td><code>&lt;xs:element name=&quot;Transit&quot; type=&quot;xs:string&quot;/&gt;</code></td>
</tr>
</tbody>
</table>

element **C1_road_layouts/Traffic-calmed**

<table>
<thead>
<tr>
<th>Diagram</th>
<th>Traffic-calmed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>xs:string</td>
</tr>
<tr>
<td>Properties</td>
<td>content simple</td>
</tr>
<tr>
<td>Source</td>
<td><code>&lt;xs:element name=&quot;Traffic-calmed&quot; type=&quot;xs:string&quot;/&gt;</code></td>
</tr>
</tbody>
</table>
element `C1_road_layouts/Accidents`

<table>
<thead>
<tr>
<th>diagram</th>
<th><img src="image" alt="Accidents" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td><code>xs:string</code></td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td><code>&lt;xs:element name=&quot;Accidents&quot; type=&quot;xs:string&quot;/&gt;</code></td>
</tr>
</tbody>
</table>

complexType `C2`

<table>
<thead>
<tr>
<th>diagram</th>
<th><img src="image" alt="Diagram" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>children</td>
<td><code>C.2.1_Physical_characteristics</code>  <code>C.2.2_Circulation_and_acces</code>  <code>C.2.3_Safety</code>  <code>C.2.4_Environmental</code>  <code>C.2.5_Communications</code>  <code>C.2.6_Security</code>  <code>C.2.7_Appearance</code>  <code>C.2.8_Works_of_art</code>  <code>C.2.9_Operation</code></td>
</tr>
<tr>
<td>used by</td>
<td>element <code>Briefing_checklist_C/C.2_The_building_as_a_whole</code></td>
</tr>
<tr>
<td>annotation</td>
<td>documentation The building as a whole</td>
</tr>
</tbody>
</table>
Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

Appendix B

Ph.D. thesis
CHRISTIAN BAIER
Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

Appendix B

```xml
<xs:element name="C.2.1_Physical_characteristics" type="xs:string"/>
<xs:element name="Dimensions" type="xs:string"/>
<xs:element name="Volumes" type="xs:string"/>
<xs:element name="Number_of_storeys" type="xs:string"/>
<xs:element name="Building_phasing" type="xs:string"/>
<xs:element name="Loading" type="xs:string"/>
<xs:element name="Energy" type="xs:string"/>
<xs:element name="Flexibility_for_future_uses" type="xs:string"/>
```

Diagram of C2/C.2.1_Physical_characteristics

```
<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Volumes</th>
<th>Number_of_storeys</th>
<th>Building_phasing</th>
<th>Loading</th>
<th>Energy</th>
<th>Flexibility_for_future_uses</th>
</tr>
</thead>
</table>
```

Properties: content complex

Children: Dimensions, Volumes, Number_of_storeys, Building_phasing, Loading, Energy, Flexibility_for_future_uses

Source:
```
<xs:element name="C.2.1_Physical_characteristics">
  <xs:complexType>
    <xs:sequence>
      <xs:element name="Dimensions" type="xs:string"/>
      <xs:element name="Volumes" type="xs:string"/>
      <xs:element name="Number_of_storeys" type="xs:string"/>
      <xs:element name="Building_phasing" type="xs:string"/>
      <xs:element name="Loading" type="xs:string"/>
      <xs:element name="Energy" type="xs:string"/>
      <xs:element name="Flexibility_for_future_uses" type="xs:string"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
```

Diagram of C2/C.2.1_Physical_characteristics/Dimensions

Type: xs:string
## Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

<table>
<thead>
<tr>
<th>properties</th>
<th>content</th>
<th>simple</th>
</tr>
</thead>
<tbody>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Dimensions&quot; type=&quot;xs:string&quot;/&gt;</td>
<td></td>
</tr>
</tbody>
</table>

### element C2/C.2.1_Physical_characteristics/Volumes

- **diagram**: ![Volumes](image)
- **type**: xs:string
- **properties**: content simple
- **source**: <xs:element name="Volumes" type="xs:string"/>

### element C2/C.2.1_Physical_characteristics/Number_of_storeys

- **diagram**: ![Number_of_storeys](image)
- **type**: xs:string
- **properties**: content simple
- **source**: <xs:element name="Number_of_storeys" type="xs:string"/>

### element C2/C.2.1_Physical_characteristics/Building_phasing

- **diagram**: ![Building_phasing](image)
- **type**: xs:string
- **properties**: content simple
- **source**: <xs:element name="Building_phasing" type="xs:string"/>

### element C2/C.2.1_Physical_characteristics/Loading

- **diagram**: ![Loading](image)
- **type**: xs:string
- **properties**: content simple
- **source**: <xs:element name="Loading" type="xs:string"/>

### element C2/C.2.1_Physical_characteristics/Energy

- **diagram**: ![Energy](image)
- **type**: xs:string
- **properties**: content simple
- **source**: <xs:element name="Energy" type="xs:string"/>
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<table>
<thead>
<tr>
<th>element</th>
<th>diagram</th>
<th>type</th>
<th>properties</th>
<th>source</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2/C.2.1_Physical_characteristics/Flexibility_for_future_uses</td>
<td></td>
<td>xs:string</td>
<td>simple</td>
<td>&lt;xs:element name=&quot;Flexibility_for_future_uses&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>element</th>
<th>diagram</th>
<th>properties</th>
<th>children</th>
<th>source</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>element</th>
<th>diagram</th>
<th>type</th>
<th>properties</th>
<th>source</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2/C.2.2_Circulation_and_acces/Vertical_and_horizontal</td>
<td></td>
<td>xs:string</td>
<td>simple</td>
<td>&lt;xs:element name=&quot;Vertical_and_horizontal&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>
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**element C2/C.2.2_Circulation_and_acces/Pedestrian**

<table>
<thead>
<tr>
<th>diagram</th>
<th>Pedestrian</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Pedestrian&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>

**element C2/C.2.2_Circulation_and_acces/Mechanized**

<table>
<thead>
<tr>
<th>diagram</th>
<th>Mechanized</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Mechanized&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>

**element C2/C.2.2_Circulation_and_acces/Goods**

<table>
<thead>
<tr>
<th>diagram</th>
<th>Goods</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;Goods&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>

**element C2/C.2.2_Circulation_and_acces/People**

<table>
<thead>
<tr>
<th>diagram</th>
<th>People</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;People&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>

**element C2/C.2.2_Circulation_and_acces/handicapped_people**

<table>
<thead>
<tr>
<th>diagram</th>
<th>handicapped_people</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td>&lt;xs:element name=&quot;handicapped_people&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
</tbody>
</table>
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### element C2/C.2.2_Circulation_and_acces/Signposting

<table>
<thead>
<tr>
<th>diagram</th>
<th><img src="image" alt="Diagram" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td><code>&lt;xs:element name=&quot;Signposting&quot; type=&quot;xs:string&quot;/&gt;</code></td>
</tr>
</tbody>
</table>

### element C2/C.2.3_Safety

<table>
<thead>
<tr>
<th>diagram</th>
<th><img src="image" alt="Diagram" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>properties</td>
<td>content complex</td>
</tr>
<tr>
<td>children</td>
<td>Structural Construction Fire_in_use</td>
</tr>
<tr>
<td>source</td>
<td><code>&lt;xs:element name=&quot;C.2.3_Safety&quot;&gt;</code><a href="">xs:complexType</a><a href="">xs:sequence</a>&lt;xs:element name=&quot;Structural&quot; type=&quot;xs:string&quot;/&gt;&lt;/xs:element&gt;&lt;xs:element name=&quot;Construction&quot; type=&quot;xs:string&quot;/&gt;&lt;/xs:sequence&gt;&lt;/xs:complexType&gt;`</td>
</tr>
</tbody>
</table>

### element C2/C.2.3_Safety/Structural

<table>
<thead>
<tr>
<th>diagram</th>
<th><img src="image" alt="Diagram" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td><code>&lt;xs:element name=&quot;Structural&quot; type=&quot;xs:string&quot;/&gt;</code></td>
</tr>
</tbody>
</table>

### element C2/C.2.3_Safety/Construction

<table>
<thead>
<tr>
<th>diagram</th>
<th><img src="image" alt="Diagram" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td><code>&lt;xs:element name=&quot;Construction&quot; type=&quot;xs:string&quot;/&gt;</code></td>
</tr>
</tbody>
</table>
element C2/C.2.3_Safety/Fire

diagram

\[
\begin{array}{c}
\text{Fire}
\end{array}
\]

type xs:string

properties content simple

source

\[
<\text{xs:element name="Fire" type="xs:string"}/>
\]

element C2/C.2.3_Safety/Safety_in_use

diagram

\[
\begin{array}{c}
\text{Safety_in_use}
\end{array}
\]

type xs:string

properties content simple

source

\[
<\text{xs:element name="Safety_in_use" type="xs:string"}/>
\]

element C2/C.2.4_Environmental

diagram

\[
\begin{array}{c}
\text{C.2.4_Environmental}
\end{array}
\]

properties content complex

children Hygrothermal Sunlight Air_movement Visual_and_acoustic_and_tactile Vibration Ventilation

source

\[
<\text{xs:element name="C.2.4_Environmental">}
<\text{xs:complexType}>
<\text{xs:sequence}>
<\text{xs:element name="Hygrothermal" type="xs:string"}/>
<\text{xs:element name="Sunlight" type="xs:string"}/>
<\text{xs:element name="Air_movement" type="xs:string"}/>
<\text{xs:element name="Visual_and_acoustic_and_tactile" type="xs:string"}/>
<\text{xs:element name="Vibration" type="xs:string"}/>
<\text{xs:element name="Ventilation" type="xs:string"}>
</xs:sequence>
</xs:complexType>
</xs:element>
\]

element C2/C.2.4_Environmental/Hygrothermal

diagram

\[
\begin{array}{c}
\text{Hygrothermal}
\end{array}
\]

type xs:string

properties content simple
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source

<xs:element name="Hygrothermal" type="xs:string"/>

element C2/C.2.4_Environmental/Sunlight

diagram

<xs:element name="Sunlight" type="xs:string"/>

type xs:string

properties content simple

source

<xs:element name="Sunlight" type="xs:string"/>

element C2/C.2.4_Environmental/Air_movement

diagram

<xs:element name="Air_movement" type="xs:string"/>

type xs:string

properties content simple

source

<xs:element name="Air_movement" type="xs:string"/>

element C2/C.2.4_Environmental/Visual_and_acoustic_and_tactile

diagram

<xs:element name="Visual_and_acoustic_and_tactile" type="xs:string"/>

type xs:string

properties content simple

source

<xs:element name="Visual_and_acoustic_and_tactile" type="xs:string"/>

element C2/C.2.4_Environmental/Vibration

diagram

<xs:element name="Vibration" type="xs:string"/>

type xs:string

properties content simple

source

<xs:element name="Vibration" type="xs:string"/>

element C2/C.2.4_Environmental/Ventilation

diagram

<xs:element name="Ventilation" type="xs:string"/>

type xs:string

properties content simple

source

<xs:element name="Ventilation" type="xs:string"/>
element C2/C.2.5_Communications

```
<xs:element name="C.2.5_Communications">
  <xs:complexType>
    <xs:sequence>
      <xs:element name="Telephone" type="xs:string"/>
      <xs:element name="Staff_call" type="xs:string"/>
      <xs:element name="Video_and_computer" type="xs:string"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
```

properties: content complex

children: Telephone Staff_call Video_and_computer

source:
```
<xs:element name="C.2.5_Communications" name="C.2.5_Communications">  
  <xs:complexType>
    <xs:sequence>
      <xs:element name="Telephone" name="Telephone" type="xs:string"/>
      <xs:element name="Staff_call" name="Staff_call" type="xs:string"/>
      <xs:element name="Video_and_computer" name="Video_and_computer" type="xs:string"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
```

---

element C2/C.2.5_Communications/Telephone

```
<xs:element name="Telephone" type="xs:string"/>
```

properties: content simple

source:
```
<xs:element name="Telephone" name="Telephone" type="xs:string"/>
```

---

element C2/C.2.5_Communications/Staff_call

```
<xs:element name="Staff_call" type="xs:string"/>
```

properties: content simple

source:
```
<xs:element name="Staff_call" name="Staff_call" type="xs:string"/>
```

---

element C2/C.2.5_Communications/Video_and_computer

```
<xs:element name="Video_and_computer" type="xs:string"/>
```

properties: content simple

source:
```
<xs:element name="Video_and_computer" name="Video_and_computer" type="xs:string"/>
```
element C2/C.2.6_Security

diagram

properties
content complex

children Access_control_or_barriers Personal_security Alarm

source
<x:s:element name="C.2.6_Security">
  <xs:complexType>
    <xs:sequence>
      <xs:element name="Access_control_or_barriers" type="xs:string"/>
      <xs:element name="Personal_security" type="xs:string"/>
      <xs:element name="Alarm" type="xs:string"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>

---

element C2/C.2.6_Security/Access_control_or_barriers

diagram

properties
content simple

source
<x:s:element name="Access_control_or_barriers" type="xs:string"/>

---

element C2/C.2.6_Security/Personal_security

diagram

properties
content simple

source
<x:s:element name="Personal_security" type="xs:string"/>

---

element C2/C.2.6_Security/Alarm

diagram

properties
content simple

source
<x:s:element name="Alarm" type="xs:string"/>
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**element C2/C.2.7_Appearance**

<table>
<thead>
<tr>
<th>diagram</th>
<th>C.2.7_Appearance</th>
<th>Building_forms_symbolic_or_func...</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Proportions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Material_colours</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Finishes</td>
</tr>
</tbody>
</table>

**properties** content complex

**children** Building_forms_symbolic_or_functional Proportions Material_colours Finishes

**source**

```xml
<xs:element name="C.2.7_Appearance">
    <xs:complexType>
        <xs:sequence>
            <xs:element name="Building_forms_symbolic_or_functional" type="xs:string"/>
            <xs:element name="Proportions" type="xs:string"/>
            <xs:element name="Material_colours" type="xs:string"/>
            <xs:element name="Finishes" type="xs:string"/>
        </xs:sequence>
    </xs:complexType>
</xs:element>
```

**element C2/C.2.7_Appearance/Building_forms_symbolic_or_functional**

<table>
<thead>
<tr>
<th>diagram</th>
<th>Building_forms_symbolic_or_func...</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**type** xs:string

**properties** content simple

**source**

```xml
<xs:element name="Building_forms_symbolic_or_functional" type="xs:string"/>
```

**element C2/C.2.7_Appearance/Proportions**

<table>
<thead>
<tr>
<th>diagram</th>
<th>Proportions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**type** xs:string

**properties** content simple

**source**

```xml
<xs:element name="Proportions" type="xs:string"/>
```

**element C2/C.2.7_Appearance/Material_colours**

<table>
<thead>
<tr>
<th>diagram</th>
<th>Material_colours</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**type** xs:string

**properties** content simple

**source**

```xml
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<td>Murals Sculpture</td>
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element C2/C.2.8_Works_of_art/Murals

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element C2/C.2.8_Works_of_art/Sculpture

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Appendix B

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<tr>
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Building

C.3.1_Structure
C.3.2_External_envelope
C.3.3_Spatial_dividers_outside_the_envelope
C.3.4_Spatial_dividers_within_the_envelope
C.3.5_Services

C3

children

C.3.1_Structure  C.3.2_External_envelope  C.3.3_Spatial_dividers_outside_the_envelope  C.3.4_Spatial_dividers_within_the_envelope  C.3.5_Services

used by

element Briefing_checklist_C/C.3_Building_fabric_performance

annotation
documentation

Building Fabric performance

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1. C3/C.3.5_Services

   - Water_distribution_and_disposal
   - Heating_ventilation
   - Gas_distribution
   - Electrical
   - Telecommunications_and_computing
   - Mechanical_and_electro-mechanical
   - Transport
   - Pneumatic_and_gravity_transport
   - Safety
   - Lightning
   - Fire_protection
   - Alarms

2. C3/C.3.1_Structure

   - Foundation
   - Carcass

3. C3/C.3.1_Structure/Foundation

   - Foundation

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#### Appendix B

**element C3/C.3.1_Structure/Carcass**

<table>
<thead>
<tr>
<th>Diagram</th>
<th><code>&lt;Carcass&gt;</code></th>
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<tr>
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<tr>
<td>Children</td>
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<tr>
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<td>Properties</td>
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<td>Source</td>
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**element C3/C.3.2_External_envelope/Envelope_above_ground**

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<tbody>
<tr>
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<td>Content <code>simple</code></td>
</tr>
<tr>
<td>Source</td>
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element C3/C.3.3_Spatial_dividers_outside_the_envelope/External_vertical_dividers

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element C3/C.3.3_Spatial_dividers_outside_the_envelope/Balustrades

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```

element C3/C.3.3_Spatial_dividers_outside_the_envelope/Grilles

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```
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</tr>
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<td>content</td>
</tr>
<tr>
<td>children</td>
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<td>properties</td>
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Appendix B

**element C3/C.3.5_Services**

```
properties                          content  simple
source                             <xs:element name="Internal_staircases" type="xs:string"/>

children                           Water_distribution_and_disposal Heating_ventilation Gas_distribution Electrical Telecommunications_and_computing Mechanical_and_electro-mechanical Transport Pneumatic_and_gravity_transport Safety Lightning Fire_protection Alarms

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    <xs:element name="Gas_distribution" type="xs:string"/>
    <xs:element name="Electrical" type="xs:string"/>
    <xs:element name="Telecommunications_and_computing" type="xs:string"/>
    <xs:element name="Mechanical_and_electro-mechanical" type="xs:string"/>
    <xs:element name="Transport" type="xs:string"/>
    <xs:element name="Pneumatic_and_gravity_transport" type="xs:string"/>
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```

**element C3/C.3.5_Services/Water_distribution_and_disposal**

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diagram                            Water_distribution_and_disposal

properties                          content  simple
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```

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source <xs:element name="Water_distribution_and_disposal" type="xs:string"/>

element C3/C.3.5_Services/Heating_ventilation
diagram Heating_ventilation

type xs:string
properties content simple
source <xs:element name="Heating_ventilation" type="xs:string"/>

element C3/C.3.5_Services/Gas_distribution
diagram Gas_distribution

type xs:string
properties content simple
source <xs:element name="Gas_distribution" type="xs:string"/>

element C3/C.3.5_Services/Electrical
diagram Electrical

type xs:string
properties content simple
source <xs:element name="Electrical" type="xs:string"/>

element C3/C.3.5_Services/Telecommunications_and_computing
diagram Telecommunications_and_computing

type xs:string
properties content simple
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element C3/C.3.5_Services/Mechanical_and_electro-mechanical
diagram Mechanical_and_electro-mechanical

type xs:string
properties content simple
source <xs:element name="Mechanical_and_electro-mechanical" type="xs:string"/>
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Appendix B

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<th>Description</th>
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<td>C3/C.3.5 Services/Transport</td>
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<td>C3/C.3.5 Services/Pneumatic_and_gravity_transport</td>
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<tr>
<td>C3/C.3.5 Services/Safety</td>
<td><img src="image-url" alt="Safety Diagram" /></td>
</tr>
<tr>
<td>C3/C.3.5 Services/Lightning</td>
<td><img src="image-url" alt="Lightning Diagram" /></td>
</tr>
<tr>
<td>C3/C.3.5 Services/Fire_protection</td>
<td><img src="image-url" alt="Fire_protection Diagram" /></td>
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Appendix B

element C3/C.3.5_Services/Alarms

<table>
<thead>
<tr>
<th>Diagram</th>
<th>C3/C.3.5_Services/Alarms</th>
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</thead>
<tbody>
<tr>
<td>Type</td>
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</tr>
<tr>
<td>Properties</td>
<td>content</td>
</tr>
<tr>
<td>Source</td>
<td>&lt;xs:element name=&quot;Alarms&quot; type=&quot;xs:string&quot;/&gt;</td>
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complexType C4

<table>
<thead>
<tr>
<th>Diagram</th>
<th>C4 diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children</td>
<td>C.4.1_Zoning, C.4.2_Spatial_relationships, C.4.3_Physical_characteristics</td>
</tr>
<tr>
<td>Used by</td>
<td>Briefing_checklist_C/C.4_Grouping_of_spaces</td>
</tr>
<tr>
<td>Annotation</td>
<td>Grouping_of_Spaces</td>
</tr>
<tr>
<td>Source</td>
<td>&lt;xs:complexType name=&quot;C4&quot;&gt;</td>
</tr>
<tr>
<td></td>
<td><a href="">xs:annotation</a></td>
</tr>
<tr>
<td></td>
<td><a href="">xs:documentation</a>Grouping of Spaces&lt;/xs:documentation&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;/xs:annotation&gt;</td>
</tr>
<tr>
<td></td>
<td><a href="">xs:sequence</a></td>
</tr>
<tr>
<td></td>
<td>&lt;xs:element name=&quot;C.4.1_Zoning&quot;&gt;</td>
</tr>
<tr>
<td></td>
<td><a href="">xs:complexType</a></td>
</tr>
<tr>
<td></td>
<td><a href="">xs:sequence</a></td>
</tr>
<tr>
<td></td>
<td>&lt;xs:element name=&quot;Security&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;xs:element name=&quot;Acoustic&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;xs:element name=&quot;Sterile&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;/xs:sequence&gt;</td>
</tr>
<tr>
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<td>&lt;/xs:complexType&gt;</td>
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<td>&lt;/xs:element&gt;</td>
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<tr>
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<td>&lt;xs:element name=&quot;C.4.2_Spatial_relationships&quot; type=&quot;xs:string&quot;/&gt;</td>
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<td></td>
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element C4/C.4.1_Zoning

<table>
<thead>
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<th>C.4.1_Zoning diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Properties</td>
<td>content</td>
</tr>
<tr>
<td>Children</td>
<td>Security, Acoustic, Sterile</td>
</tr>
<tr>
<td>Source</td>
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</tr>
<tr>
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</tr>
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<td></td>
<td><a href="">xs:sequence</a></td>
</tr>
<tr>
<td></td>
<td>&lt;xs:element name=&quot;Security&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;xs:element name=&quot;Acoustic&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;/xs:sequence&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;/xs:complexType&gt;</td>
</tr>
</tbody>
</table>
Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector

Appendix B

<table>
<thead>
<tr>
<th>element</th>
<th>diagram</th>
<th>type</th>
<th>properties</th>
<th>source</th>
</tr>
</thead>
<tbody>
<tr>
<td>C4/C.4.1_Zoning/Sterile</td>
<td><img src="image" alt="Sterile" /></td>
<td>xs:string</td>
<td>content simple</td>
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<tr>
<td>C4/C.4.1_Zoning/Acoustic</td>
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<td>content simple</td>
<td>&lt;xs:element name=&quot;Acoustic&quot; type=&quot;xs:string&quot;/&gt;</td>
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<tr>
<td>C4/C.4.1_Zoning/Sterile</td>
<td><img src="image" alt="Sterile" /></td>
<td>xs:string</td>
<td>content simple</td>
<td>&lt;xs:element name=&quot;Sterile&quot; type=&quot;xs:string&quot;/&gt;</td>
</tr>
<tr>
<td>C4/C.4.2_Spatial_relationships</td>
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<td>xs:string</td>
<td>content simple</td>
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</tr>
<tr>
<td>C4/C.4.3_Physical_characteristics</td>
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<td>xs:string</td>
<td>content simple</td>
<td>&lt;xs:element name=&quot;C.4.3_Physical_characteristics&quot; type=&quot;xs:string&quot;/&gt;</td>
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</tbody>
</table>
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Appendix B

### C.5.3_Relationship_to_other_spaces

```xml
<xs:element name="C.5.3_Relationship_to_other_spaces" type="xs:string"/>
```

### C5/C.5.4_Building_services

```xml
<x:element name="C.5.4_Building_services" type="xs:string"/>
```

### C6

```xml
<xs:complexType name="C6">
  <xs:annotation>
    <xs:documentation>Einrichtung, Ausstattung, Möbel</xs:documentation>
  </xs:annotation>
  <xs:sequence>
    <xs:element name="C.6.1_Items_listed_by_category" type="xs:string"/>
    <xs:element name="C.6.2_Location_and_area_of_use" type="xs:string"/>
    <xs:element name="C.6.3_Installation" type="xs:string"/>
    <xs:element name="C.6.4_Appearance" type="xs:string"/>
    <xs:element name="C.6.5_Maintenance" type="xs:string"/>
  </xs:sequence>
</xs:complexType>
```

---

**Element C5/C.5.4.Building_services**

**Diagram**

![Diagram of C6](image)

**Type** xs:string

**Properties**

- content: simple

**Source**

```xml
<x:element name="C.5.4_Building_services" type="xs:string"/>
```

**Complex Type C6**

**Diagram**

![Diagram of C6](image)

**Children**

- C.6.1_Items_listed_by_category
- C.6.2_Location_and_area_of_use
- C.6.3_Installation
- C.6.4_Appearance
- C.6.5_Maintenance

**Used By**

- element: Briefing_checklist C/C.6_Plant_equipment_and_furnishings

**Source**

```xml
<xs:complexType name="C6">
  <xs:annotation>
    <xs:documentation>Einrichtung, Ausstattung, Möbel</xs:documentation>
  </xs:annotation>
  <xs:sequence>
    <xs:element name="C.6.1_Items_listed_by_category" type="xs:string"/>
    <xs:element name="C.6.2_Location_and_area_of_use" type="xs:string"/>
    <xs:element name="C.6.3_Installation" type="xs:string"/>
    <xs:element name="C.6.4_Appearance" type="xs:string"/>
    <xs:element name="C.6.5_Maintenance" type="xs:string"/>
  </xs:sequence>
</xs:complexType>
```
element C6/C.6.1_Items_listed_by_category

```
<xs:element name="C.6.1_Items_listed_by_category" type="xs:string"/>
<xs:element name="Sanitary_appliances" type="xs:string"/>
<xs:element name="Storage" type="xs:string"/>
```

properties
- content: complex
- children: Sanitary_appliances, Storage

source
```
<xs:element name="C.6.1_Items_listed_by_category">
  <xs:complexType>
    <xs:sequence>
      <xs:element name="Sanitary_appliances" type="xs:string"/>
      <xs:element name="Storage" type="xs:string"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
```

element C6/C.6.1_Items_listed_by_category/Sanitary_appliances

```
<xs:element name="Sanitary_appliances" type="xs:string"/>
```

properties
- content: simple
- source: Sanitary_appliances

type: xs:string
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element C6/C.6.1_Items_listed_by_category/Storage

```xml
<xs:element name="Storage" type="xs:string"/>
```

element C6/C.6.2_Location_and_area_of_use

```xml
<xs:complexType>
  <xs:sequence>
    <xs:element name="Room" type="xs:string"/>
    <xs:element name="Zone" type="xs:string"/>
    <xs:element name="Outdoors" type="xs:string"/>
  </xs:sequence>
</xs:complexType>
```

children Room Zone Outdoors

source

```xml
<xs:element name="C.6.2_Location_and_area_of_use">
  <xs:complexType>
    <xs:sequence>
      <xs:element name="Room" type="xs:string"/>
      <xs:element name="Zone" type="xs:string"/>
      <xs:element name="Outdoors" type="xs:string"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
```

element C6/C.6.2_Location_and_area_of_use/Room

```xml
<xs:element name="Room" type="xs:string"/>
```

element C6/C.6.2_Location_and_area_of_use/Zone

```xml
<xs:element name="Zone" type="xs:string"/>
```
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<table>
<thead>
<tr>
<th>element C6/C.6.2_Location_and_area_of_use/Outdoors</th>
</tr>
</thead>
<tbody>
<tr>
<td>diagram: <img src="image1" alt="Outdoors" /></td>
</tr>
<tr>
<td>type: <code>xs:string</code></td>
</tr>
<tr>
<td>properties: <code>content</code> simple</td>
</tr>
<tr>
<td>source: <code>&lt;xs:element name=&quot;Outdoors&quot; type=&quot;xs:string&quot;/&gt;</code></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>element C6/C.6.3_Installation</th>
</tr>
</thead>
<tbody>
<tr>
<td>diagram: <img src="image2" alt="C.6.3_Installation" /></td>
</tr>
<tr>
<td>properties: <code>content</code> complex</td>
</tr>
<tr>
<td>children: <code>Fixed_or_loose_or_mobile</code>, <code>Service_connections</code>, <code>Assembly</code></td>
</tr>
<tr>
<td>source: <code>&lt;xs:element name=&quot;C.6.3_Installation&quot;&gt;</code></td>
</tr>
</tbody>
</table>

```xml
<xs:element name="C.6.3_Installation">
  <xs:complexType>
    <xs:sequence>
      <xs:element name="Fixed_or_loose_or_mobile" type="xs:string"/>
      <xs:element name="Service_connections" type="xs:string"/>
      <xs:element name="Assembly" type="xs:string"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
```

<table>
<thead>
<tr>
<th>element C6/C.6.3_Installation/Fixed_or_loose_or_mobile</th>
</tr>
</thead>
<tbody>
<tr>
<td>diagram: <img src="image3" alt="Fixed_or_loose_or_mobile" /></td>
</tr>
<tr>
<td>type: <code>xs:string</code></td>
</tr>
<tr>
<td>properties: <code>content</code> simple</td>
</tr>
<tr>
<td>source: <code>&lt;xs:element name=&quot;Fixed_or_loose_or_mobile&quot; type=&quot;xs:string&quot;/&gt;</code></td>
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</table>

<table>
<thead>
<tr>
<th>element C6/C.6.3_Installation/Service_connections</th>
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</thead>
<tbody>
<tr>
<td>diagram: <img src="image4" alt="Service_connections" /></td>
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<tr>
<td>type: <code>xs:string</code></td>
</tr>
<tr>
<td>properties: <code>content</code> simple</td>
</tr>
<tr>
<td>source: <code>&lt;xs:element name=&quot;Service_connections&quot; type=&quot;xs:string&quot;/&gt;</code></td>
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</table>
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**element C6/C.6.3_Installation/Assembly**

<table>
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<tr>
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<th><img src="image" alt="Assembly" /></th>
</tr>
</thead>
<tbody>
<tr>
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<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
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</tr>
</tbody>
</table>

**element C6/C.6.4_Appearance**

<table>
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<tr>
<th>diagram</th>
<th><img src="image" alt="C.6.4_Appearance" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>properties</td>
<td>content complex</td>
</tr>
<tr>
<td>children</td>
<td>Materials Colours</td>
</tr>
<tr>
<td>source</td>
<td><code>&lt;xs:element name=&quot;C.6.4_Appearance&quot;&gt;</code></td>
</tr>
<tr>
<td></td>
<td><code>&lt;xs:complexType&gt;</code></td>
</tr>
<tr>
<td></td>
<td><code>&lt;xs:sequence&gt;</code></td>
</tr>
<tr>
<td></td>
<td><code>&lt;xs:element name=&quot;Materials&quot; type=&quot;xs:string&quot;/&gt;</code></td>
</tr>
<tr>
<td></td>
<td><code>&lt;xs:element name=&quot;Colours&quot; type=&quot;xs:string&quot;/&gt;</code></td>
</tr>
<tr>
<td></td>
<td><code>&lt;/xs:sequence&gt;</code></td>
</tr>
<tr>
<td></td>
<td><code>&lt;/xs:complexType&gt;</code></td>
</tr>
<tr>
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</tr>
</tbody>
</table>

**element C6/C.6.4_Appearance/Materials**

<table>
<thead>
<tr>
<th>diagram</th>
<th><img src="image" alt="Materials" /></th>
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</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
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</tr>
</tbody>
</table>

**element C6/C.6.4_Appearance/Colours**

<table>
<thead>
<tr>
<th>diagram</th>
<th><img src="image" alt="Colours" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content simple</td>
</tr>
<tr>
<td>source</td>
<td><code>&lt;xs:element name=&quot;Colours&quot; type=&quot;xs:string&quot;/&gt;</code></td>
</tr>
</tbody>
</table>
element C6/C.6.5_Maintenance

- **Diagram:**
  - C.6.5_Maintenance
    - Life-span
    - Cleaning
    - Maintenance_control
    - Handbook

- **Properties:**
  - Content: complex
  - Children: Life-span, Cleaning, Maintenance_control, Handbook

- **Source:**
  

```xml
<xs:element name="C.6.5_Maintenance">
  <xs:complexType>
    <xs:sequence>
      <xs:element name="Life-span" type="xs:string"/>
      <xs:element name="Cleaning" type="xs:string"/>
      <xs:element name="Maintenance_control" type="xs:string"/>
      <xs:element name="Handbook" type="xs:string"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
```

---

**element C6/C.6.5_Maintenance/Life-span**

- **Diagram:**
  - Life-span

- **Type:** xs:string

- **Properties:**
  - Content: simple

- **Source:**
  

```xml
<xs:element name="Life-span" type="xs:string"/>
```

---

**element C6/C.6.5_Maintenance/Cleaning**

- **Diagram:**
  - Cleaning

- **Type:** xs:string

- **Properties:**
  - Content: simple

- **Source:**
  

```xml
<xs:element name="Cleaning" type="xs:string"/>
```

---

**element C6/C.6.5_Maintenance/Maintenance_control**

- **Diagram:**
  - Maintenance_control

- **Type:** xs:string

- **Properties:**
  - Content: simple

- **Source:**
  

```xml
<xs:element name="Maintenance_control" type="xs:string"/>
```
### element C6/C.6.5_Maintenance/Handbook

<table>
<thead>
<tr>
<th>diagram</th>
<th><img src="Handbook.png" alt="Handbook" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>xs:string</td>
</tr>
<tr>
<td>properties</td>
<td>content  simple</td>
</tr>
<tr>
<td>source</td>
<td><code>&lt;xs:element name=&quot;Handbook&quot; type=&quot;xs:string&quot;/&gt;</code></td>
</tr>
</tbody>
</table>

Resumen extendido de la tesis doctoral

*Development of a process model for the holistic use of BIM methodology for sustainable construction in the public sector.*

*Desarrollo de un modelo de proceso para el uso holístico de la metodología BIM para la construcción sostenible en el sector público.*

*Entwicklung eines Prozessmodells für den holistischen Einsatz der BIM Methodik im nachhaltigen öffentlichen Bauen.*

Autor / Author
CHRISTIAN KARL BAIER

Directores / Advisors
DR. DANIEL CASTRO FRESNO
DR. JOAQUIN DIAZ

Santander, Enero 2016
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1 Resumen de la tesis

El trabajo con la metodología BIM es un proceso de aplicación en todo el mundo (wikipedia, 2015a), incluido en el sector público de la construcción (Porwal and Hewage, 2013). Una ventaja del trabajo con la metodología BIM es que conlleva mejoras en la calidad de la construcción como la reducción de los costes y los tiempos de construcción (Bryde et al., 2013; Yan and Damian, 2008). La metodología BIM ofrece un proceso mejorado y continuo de diseño, construcción y operación, creando por tanto un valor añadido a lo largo de todas las fases de su ciclo de vida (Diaz, 2013). Es bien sabido que no sólo la fase de puesta en marcha, sino también la de operación de una obra, necesita de un soporte financiero (Woodward, 1997). El diseño, la construcción y el modo de operación de los edificios ha cambiado de forma sustancial. Ingenieros, arquitectos o responsables de planificación emplean ya de forma cotidiana herramientas o dispositivos digitales. Este cambio provoca un aumento en la coherencia de la información y la cooperación entre todas las partes involucradas. Los vacíos de información y la discontinuidad de los medios de comunicación se reducen significativamente. A través de los resultados de este cambio y de la aplicación de la metodología BIM en la planificación, los procesos de construcción y operación reducen por tanto sus costes, asegurando que se cumplen las fechas límite y mejorando la calidad de la obra. Para una correcta aplicación de la metodología BIM, la densidad de información en el inicio de un proceso de planificación debe ser alta. Además, esta información debe estar verificada, validada y ser fiable. La verificación y la validación se pueden llevar a cabo de acuerdo a un sistema de certificación de la sostenibilidad. Esto supondría una buena base para la mejora de todos los procesos subsiguientes. Además, la capacidad de influir en el coste al inicio del proceso de diseño es mayor: los costes asociados a los cambios son menores que en una fase de diseño avanzada. Así, una información inicial fiable y de alta densidad no sólo promueve una aplicación integral (global) de la metodología BIM en el sector de la construcción pública. Además, esto da lugar a sinergias adicionales. Las decisiones en etapas tempranas del diseño son posibles, lo que supone un aumento de la rentabilidad y de la calidad de la construcción. Una solución pa-
Desarrollo de un modelo de proceso para el uso holístico de la metodología BIM para la construcción sostenible en el sector público.

ra asegurar estos requisitos de información es la planificación de necesidades, que permite que se pueda definir una gran cantidad de información de la obra antes del inicio del período de ejecución. La planificación de necesidades se utiliza para la determinación sistemática de la información asociada a la obra con el objetivo de mejorar la calidad y reducir los costes (Deutsche Indus-

trienorm, 1996). En el sector de la construcción pública se utiliza la norma DIN 18205, que es una traslación de la norma ISO 9699:1994 (International Stan-
dard, 1994). La información de esta norma, proporcionada a través de la vali-
dación y verificación al comienzo de la aplicación de la metodología BIM, se evalúa desde la perspectiva de la sostenibilidad, y está consensuada con un gran número de actores involucrados. En muchos casos, en el sector público, y a pesar de la utilización de la norma DIN 18205, hay una falta de información adecuada en las etapas iniciales del proceso constructivo (Hodulak and Sch-
ramm, 2011). Esta falta de información tiene un impacto negativo en los costes y el cumplimiento de las fechas límite, así como en la calidad de la obra. Las deficiencias en la información en las fases iniciales del diseño se deben a que no se ha llevado a cabo una planificación de necesidades de acuerdo a la norma DIN 18205 ni se hecho interoperable y en formato digital. La planifica-
ción de necesidades según DIN 18205 existe sólo en forma de sistema des-
centralizado y analógico en documentos físicos. Esto provoca que los vacíos de información y las discontinuidades en medios de comunicación ocurran ya en la fase de diseño. Se da, por tanto, un gran déficit en la continuidad de la información producida en a lo largo de todo el ciclo de vida.

El status quo muestra que no existe actualmente un uso integrado de la informa-
ción de la norma DIN 18205 con la metodología BIM. Así, en base a lo mencionado, el uso o validación de la información de la norma DIN 18205 en conjunto con la metodología BIM es inexistente durante las fases de diseño, ejecución y uso. Sin embargo, la planificación de necesidades es un proceso de mucha importancia en el ciclo de vida de la construcción. Por tanto, el objeti-
tivo de este trabajo es diseñar, elaborar y presentar un sistema para la aplica-
ción de la metodología BIM en el sector de la construcción civil de forma que tenga aspectos de sostenibilidad. Se trata de un enfoque holístico basado en la
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Consideración que de la sostenibilidad hace la BNB (Bewertungssystem nachhaltiges Bauen/Sistema de clasificación construcción sostenible) y basado en la aplicación de la metodología BIM en el sector de la construcción pública. Para ello, se define y se desarrolla un nuevo esquema XML teniendo en cuenta los requisitos de la norma DIN 18205.
2 Alcance y objetivo de esta tesis

El objetivo de esta tesis era diseñar, elaborar y presentar una metodología para la aplicación de la metodología BIM en el sector público de la construcción teniendo en cuenta aspectos de sostenibilidad. Los capítulos de esta tesis se orientaron a la verificación de las conexiones entre la metodología BIM y la sostenibilidad en el sector público de la construcción. Los resultados de los estudios mostrados en los capítulos han demostrado que los enfoques están disponibles, pero la conexión fundamental aún no prevalece.

Con este objetivo fundamental, se analizaron los siguientes temas:

- Definición del término BIM incluyendo todos sus posibles aspectos y sus limitaciones respecto a otros métodos digitales de trabajo.

- Análisis de la aplicación a nivel mundial de la metodología BIM en el sector público de la construcción.

- Estudio de los modelos existentes en el mundo para evaluar la madurez de la metodología BIM en una empresa o proyecto.

- Aplicación de la interfaz interoperable IFC (Industry Foundation Classes) utilizada a nivel mundial, incluido el sector público de la construcción.

- Análisis de la sostenibilidad en la construcción y en particular de la calidad de los procesos por parte del BNB (Bewertungssystem Nachhaltiges Bauen/Assessment System Sustainable Building) para la construcción en el sector público.

A partir de estos análisis se demostró la compatibilidad entre el enfoque holístico considerado en el análisis de la sostenibilidad realizado por el BNB y la aplicación de la metodología BIM en el sector público de la construcción. Mediante la implementación e integración digital de la norma DIN 18205 en un
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Un nuevo esquema XML se asegura todo el proceso de diseño, construcción y explotación. Esto hace que sea posible que la información que se ha definido sistemáticamente de acuerdo a la norma DIN 18205 pueda ser revisada de acuerdo a la BNB. El resultado de esta revisión es un ciclo de vida del diseño optimizado. Además se facilita la aplicación de la metodología BIM. Las decisiones de diseño se pueden tomar en etapas anteriores, de forma que se asegura la provisión de la información necesaria para la aplicación de la metodología BIM. De este modo se está asegurando un ahorro de costes durante todo el ciclo de vida (véase la Figura 62) y mientras se aplica la metodología BIM (véase la Figura 64). Otros ahorros son el resultado de un proceso de cambio a través de la implementación y la integración digital de DIN 18205 en un nuevo esquema XML. Por primera vez la información determinada sistemáticamente está ya disponible en formato digital, permitiendo la interoperabilidad en el diseño y también en etapas posteriores de la obra. Además, se eliminan los vacíos de información y las discontinuidades de los medios de comunicación. Esto significa que la información se determina sola una vez y no en repetidas ocasiones para cada fase, lo que resulta en un ahorro en cada fase del diseño, construcción y explotación, comenzando por los costes asociados al auditor BNB, que utiliza la información de la BI-18205.

Fig. 1. Información de la construcción a través BI-18205
3 Resumen de los resultados

Building information Modelling (BIM) ha sido durante los últimos 20 años aproximadamente una metodología representativa de un pensamiento holístico y de un modo de trabajo digital en el diseño, construcción y uso. La terminología ya se utilizaba con un significado similar aproximadamente ya en el año 1970. En los años 1970 se usaban los conceptos Building Product Models o Product Information Models para describir el concepto, la tecnología y el método necesario en relación con todas las fases de la construcción de un edificio.

La metodología BIM combina muchos servicios diferentes, tales como cálculo de costos, gestión del ciclo de vida, estudios de sostenibilidad, los cálculos de la eficiencia energética, etc. Sin embargo, dependiendo de los niveles de orientación profesional y capacidades de las personas hay una amplia variedad de perspectivas así como diferencias en los requisitos de rendimiento relacionados con el grado de integración de la metodología BIM y el alcance de servicios que abarca. Hay diferencias en el potencial de usuario, problemas y procesos. La precondición de una integración libre de errores y de eficiente integración es el establecimiento de un marco operativo consistente para la aplicación de la metodología BIM.

La investigación del uso de la metodología BIM en el sector público de la construcción muestra que su uso se ha vuelto obligatorio en algunos países mediante las correspondientes normas y manuales. En todos los países donde el uso de la metodología BIM es obligatorio, las bases para este requisito han sido normas o manuales creadas exclusivamente del institución de Estado. Tales instituciones normalmente están involucradas en el sector público de la construcción, y gestionan un gran número de edificios. Hay algunas restricciones en los proyectos, tales como las dimensiones de espacio o los costes que dejan fuera la aplicación obligatoria. Sin embargo, se debería observar que la cooperación con estas instituciones es sólo posible si la metodología BIM se usa desde el lado de la empresa. El pensamiento detrás de este requisito obligatorio es mejorar la eficiencia de los procesos de planificación, construcción y...
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de procedimiento. Esto es necesario debido al gran número de edificios que deben ser gestionados. La metodología BIM se usa como un medio para gestionar eficiente y de alta calidad los edificios. Al considerar las normas y manuales existentes, se hace evidente que no se trata de descripciones técnicas complicadas, sino más bien de la base de un lenguaje común para el manejo de los proyectos con la metodología BIM. El marco sirve como una especie de explicación entre el contratista y la institución del Estado, garantizando así la comunicación dentro del proyecto. Las convenciones semánticas hacen posible y facilitan el trabajan complejo software de BIM. Este enfoque se apoya en normas especialmente desarrolladas para los estándares de metodología de BIM. Estas normas incluyen estándares ISO, que sirven como base para un uso conjunto y que dan más información sobre las normas existentes. Se puede observar una cercana cooperación en todos los Estados donde el buildingSMART está disponible.

El procedimiento de introducción obligatoria de la metodología BIM en el sector público en el Reino Unido muestra la introducción simultánea de normas en forma de estándares de la industria. La introducción de una metodología BIM obligatoria en el sector público de la construcción se ilustra con un modelo de madurez, denominado “rampa BIM evolutiva”. En paralelo con esto, el desarrollo de estándares de industria necesarios se especifica basado en claros requisitos que se aplican al BIM. El último propósito en Gran Bretaña es alcanzar un nuevo estándar de interoperabilidad. Sin embargo, en vez de ser usado para evaluar el nivel de madurez dentro de una institución o de un proyecto, el modelo de madurez en Gran Bretaña es una hoja de ruta para un desarrollo que marcan la ruta de viaje necesaria en el desarrollo de un Building Information Model integrada que proporciona valor añadido para todas las partes involucradas a través del ciclo de vida de un edificio y les ayuda a usar el modelo de información del edificio consistentemente. Los otros modelos de madurez de BIM que aparecen determinan el nivel de madurez. Esto presupone que un conocimiento básico de la BIM está presente. Esto puede llevar a complicaciones en el caso de una autoevaluación por ausencia de conocimiento, ciertas cuestiones posiblemente pueden ser contestadas de forma incorrecta o no.
respondidas. Aquí el modelo de TNO constituye una particularidad. En el Quicksans de TNO, un auditor es responsable de que se responden correctas. Además, estos pueden dar asistencia con las preguntas, de manera de promover las respuestas correctas y precisas. Los otros modelos de madurez destacados conservan, sin embargo, su validez para el uso. Ellos permiten determinan la madurez de BIM, y esto ayuda al seleccionar una empresa. Permiten que se forme una opinión acerca de la competencia de una empresa en el uso de BIM. El nivel de experiencia en el uso de BIM en un proyecto también se específica.

La base para el uso de BIM y la metodología correspondiente es la interoperabilidad. La estructura de buildingSMART y el alto involucramiento de sus capítulos en muchos países promueve el desarrollo independiente de la interfaz de la IFC. La aplicación especialmente tiene un gran ventaja para sector público de la construcción en relación con la metodología BIM. La interfaz es la única estándar del mundo operativa, sin propietario, para intercambiar información digital en la industria de la construcción. Además, a través de esta interfaz no sólo se puede cambiar la información geométrica, sino también más importante, permite la transferencia sin errores entre las partes involucradas de otros importantes parámetros de una construcción. Es posible hacer información orientada a objetos y otras descripciones típicas de una construcción en forma interoperable durante de todo el ciclo de vida. Estas son las ventajas decisivas comparadas con una interfaz propietaria. La tecnología para este intercambio la proporciona la interfaz IFC. IFC fue presentado en 1997 en el marco del desarrollo de las normas ISO estándar STEP como la primera interfaz no -propietaria en la construcción. Desde entonces, se amplía siendo constantemente desarrollada y adaptada a las necesidades de la industria de la construcción. El cambio al concepto de plataforma de IFC permite un uso controlado, trazable y comprensible para otras áreas de la construcción utilizando el MVD. El entendimiento de la semántica dentro de la interfaz está asegurada por el IFD. Por IFD se proporciona información orientada a objetos relacionados con el producto en diferentes idiomas y, por lo tanto, garantiza la disponibilidad internacional de intercambio de información. Todos los componentes
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mencionados, como la IFC, MVD y IFD se basan en la norma ISO, son normas que de este modo garantizan una correcta aplicación en todo el mundo. Con la versión de interfaz IFC 4.0 es posible por primera vez intercambiar información sostenible.

Desde algunas décadas el aspecto de la perspectiva sostenible en los recursos de la Tierra tiene lugar por sensibilización hacia temas específicos. La industria de la construcción tiene una gran parte como consumidor de recursos naturales y tiene un rol considerable en un futuro sostenible desde el uso cuidadoso de los recursos limitados. Debido a esta perspectiva sostenible, los sistemas de evaluación de la sostenibilidad han emergido en el sector de la construcción en paralelo con estrategia de sostenibilidad global prevaleciente. En general, se evalúan la construcción basándose en aspectos de sostenibilidad desde la fase de proyecto en adelante e incluye el cambio de uso o demolición. Para eso existen diferentes sistemas que pueden ser utilizados a nivel nacional o internacional. Dependiendo de la ubicación, los sistemas tienen aplicaciones especiales. Esto depende del enfoque para la evaluación en cuestión de la sostenibilidad del país. Al observar la historia de estos sistemas y la comparación del contenido de los tópicos de evaluación se revela que hay paralelos entre el contenido de los sistemas más amplios. Estos paralelos también se relacionan con su capacidad de ser utilizados internacionalmente. A partir de estas conclusiones, el sistema BNB de certificación de sostenibilidad se examinó con mayor detalle. Se estableció que los criterios de calidad del proceso, en particular el criterio de preparación del proyecto, proporcionan un valor añadido de alto valor en relación con la evaluación de la sostenibilidad, y también en relación con el uso de la metodología BIM en el sector público de la construcción. Esto llevó a proponer una solución combinando la metodología BIM en el sector público de la construcción con la sostenibilidad en una forma interoperable, digital.

La sostenibilidad se revisa como parte del criterio de preparación del proyecto en la planificación de necesidades. La planificación de necesidades se puede usar como una forma de gestión de la calidad del proceso de planificación así
como de los siguiente procesos. Como la estándar de planificación de necesidades existente está ya claramente especificada en DIN y en la ISO, los métodos en sector público de la construcción están especificados de manera nacional e internacional. Es más, la planificación de necesidades tiene una influencia positiva en muchos de los procesos involucrados en la metodología BIM así como en muchos relacionados con la evaluación de la sostenibilidad BNB. El llevar a cabo el proceso de planificación de necesidades de manera digital proporciona oportunidades para mejoras recíprocas de eficiencia y calidad. Gracias a las sinergias que se alcanzan a través de la metodología BIM y relacionadas con la sostenibilidad, se escogió implementar e integrar la DIN 18205 en un nuevo esquema XML.
4 Significado académico y práctico del contenedor

La presentación de la planificación de necesidades en forma de contenedor: Modelo de DIN 18205 en un esquema XML, supone la base de una solución interoperable y digital. El esquema XML describe las necesidades (los requisitos) en relación a la información necesaria así como a su contenido. Todo esto está expresado y definido claramente en el esquema. Tanto el tipo de información como el rango de valores están claramente delineados. El mapeo digital de los procesos de la planificación de necesidades en forma de contenedor en un nuevo esquema XML proporciona una clara descripción de cómo obtener la información requerida. Esta claridad en la descripción es posible gracias al lenguaje XML. Como IFC, el XML un estándar se define de forma uniforme y global a través de W3C. El estándar es libre de costo y por lo tanto, al alcance de todos. Además, el ASCII es un sistema de codificación basado en texto que es legible por humanos y máquinas. Es aplicable tanto al esquema como al documento XML. El esquema XML se usa para definir un archivo plantilla para un documento XML: el BI-18205. Durante la planificación de necesidades, la información es, por tanto, almacenada en BI-18205, de forma que puede estar disponible de forma digital e interoperable para cualquiera de las partes involucradas a medida que el proyecto avanza. Esto se puede hacer con programas específicos del fabricante como hojas de cálculo, si bien puede también darse como parte del proceso de planificación digital. La información puede utilizarse también para la realización de comprobaciones. La información geométrica se puede comparar con la información en el BI-18205. En todas las fases del proyecto la metodología BIM hace posible la validación de la información en el BI-18205 respecto a la información relativa al edificio en construcción. También parece lógico utilizar el BI-18205 en el BNB tanto dentro como fuera de la principal grupo de criterios la cualidad de proceso Esta información puede además utilizarse para evaluar criterios pertenecientes a otros grupos de criterios durante la fase de preparación del proyecto. Cualquier cambio requerido en diseño inicial es consecuentemente trasladado a una fase que en ningún caso es
crítica respecto al tiempo. Además, las condiciones de contorno que no suelen clarificarse hasta la fase de diseño, se tratan en una etapa muy anterior gracias a la planificación de necesidades BI-18205, siendo extendidas a todas las partes involucradas.

Este trabajo es una representación del status quo relativo a la aplicación de la metodología BIM en el sector público de la construcción. Además, se ha llevado a cabo una revisión de su posible empleo en la construcción sostenible. Esto supone una visión de conjunto (global) de los sistemas de certificación de la sostenibilidad en el campo de la construcción y del uso de la metodología BIM en el sector público de la construcción. Ambos mundos se unen en el BI-18205, lo que es posible gracias al uso de información idéntica y definida de forma precisa. Esta información puede emplearse tanto en el campo de la sostenibilidad como en el de la metodología BIM. Además, la información puede representarse y actualizarse utilizando métodos digitales e interoperables. Las normas DIN e ISO actuales permiten emplear estos métodos de forma global.
5 Futuras líneas de investigación

La globalización progresiva, que afecta también a la industria de la construcción, exige un replanteamiento en la forma de trabajar. Si se observan los esquemas de certificación de sostenibilidad utilizados, se descubre que existen similitudes entre ellos. Una de las razones es sin duda la estrategia global de sostenibilidad y los objetivos de los esquemas de certificación de la sostenibilidad en el sector de la construcción a partir de los cuales han derivado los de los diferentes países. Debe llevarse a cabo un análisis detallado hasta el punto en que la planificación de necesidades relativa al Indicador -1 sea transferible desde el BNB a la calidad del proceso de cualquier otro sistema de certificación de la sostenibilidad.

La aplicación de la metodología BIM es vista también por los fabricantes de los sistemas BIM desde una perspectiva global. Cuando se venden estos programas, nada cambia aparte del idioma y del interfaz de usuario. buildingSMART ha reconocido esta creación global de valor a una etapa muy temprana, promoviendo la participación global, con una perspectiva internacional, en la metodología BIM a través de su modelo de negocio. Para una aplicación global y uniforme de la metodología BIM son necesarios estándares de la Industria. Además, son necesarios tanto a nivel nacional como internacional. Sin un estándar común, nacional o internacional, el empleo productivo y exitoso de la metodología BIM es difícil de implementar. Así, para un adecuado y exitoso lanzamiento de la metodología BIM es necesario también cambiar los contratos en el sector de la construcción, de servicios que van a ser suministrados por dicha metodología. Sin lugar a dudas, la motivación en el uso del BIM es principalmente, y por naturaleza, económica. Y es una motivación perfectamente entendible en una economía de mercado.

Los cambios contractuales y el desarrollo de normas para la aplicación de la metodología BIM son procesos absolutamente necesarios para la introducción de la metodología BIM. El uso de normas desarrolladas en este campo como la BI-18205 permite que la información relativa a la construcción/al edificio pueda
ser utilizada sin barreras. La información del BIM puede por tanto ser utilizada en el sector de la construcción pública, siendo esta información multidisciplinaria. Este le da un gran potencial en cuanto al uso orientado a objetos y al empleo del BIM a lo largo del ciclo de vida. El uso integral del modelado de la información de la construcción es posible gracias a la inclusión de información relevante en forma de una dimensión adicional (coste, planificación, etc.). Un marco coherente en forma de organismos de normalización o normativas haría posible el acceso automático a la información, lo que simplificaría el procesado de esa información por parte del sector público en tareas tales como la administración de grandes áreas de construcción.

El desarrollo del contenido contractual y nuevas normas uniformes son pilares para promover la interoperabilidad, que es un elemento esencial de la metodología BIM en el sector público de la construcción. El continuo desarrollo de la interfaz IFC para el intercambio digital de la información necesaria mediante BIM es inevitable e influye en la elaboración de nuevas normas y manuales. Los cada vez más exigentes requisitos hacen que una adecuada interfaz no propietaria para el trabajo sea cada vez más importante para las disciplinas específicas responsables de los componentes técnicos del edificio. En los países en los que el uso de BIM es obligatorio, es necesario un examen más profundo de los procesos existentes. De la investigación aquí realizada pueden extraerse conclusiones que promuevan el desarrollo global de la metodología BIM en el sector público de la construcción de forma paralela a la sostenibilidad.
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