Christoph Carl Eichler | Christian Schranz | Tina Krischmann | Harald Urban

BIMcert Handbook

Basic Knowledge openBIM

Edition 2023

buildingSMART Austria

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The idea for this book was developed in the course of the research project BIM-Zert – *Standardised Qualification and Certification Model for Building Information Modeling in Austria*. This research project was funded by the Austrian Federal Ministry for Digital and Economic Affairs (BMDW) in the course of the FFG *Qualification Networks* track *(4th call for proposals)* track in the FFG *Research Competences for Industry* programme.

IMPRESSUM

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buildingSMART Austria

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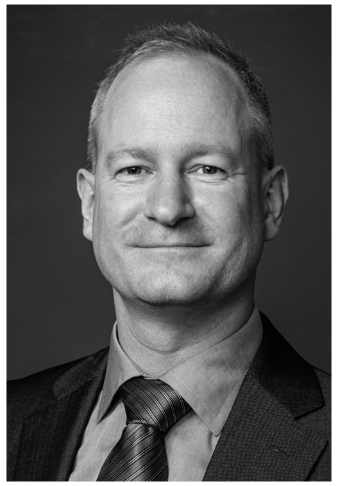

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Simon Fischer
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Thomas Glättli
is Co-Managing Director of »Bauen digital Schweiz« / buildingSMART Switzerland and Head of Use Case Management Service at buildingSMART International. He has a strong background in the building technology industry and has previously worked for international companies in leading product management positions. In addition to multinational project management and data lifecycle management, digitalisation has always been a focus of his responsibilities. He holds a BSc degree in Engineering and an Executive MBA from the University of St. Gallen in Switzerland. As a consultant to the AEC industry, he continues to drive and promote digital transformation.
He is passionate about knowledge transfer and consulting. As a guest lecturer, he teaches at several universities of applied sciences and advises numerous initiatives in the construction industry.

Hannes Asmera
is responsible for BIM project management and controlling in building construction and infrastructure projects, as well as the BIM-based further development of various topics relating to BIM processes and their content. As one of the first *Certified Trainers* (BIM) of buildingSMART Austria and a member of the examination board, he is regularly involved in the BIM training of future BIM experts. In the EU-funded digitisation project »BRISE-Vienna« for developing a digital building submission and building permit, he was the deputy work package leader responsible for developing the specifications and test routines. Before this, the native Viennese held a leading position in BIM quality management, trained nationally/internationally as a certified Solibri trainer and acted as a consultant for BIM quality management and its processes in projects. As a member of the Austrian Standards Committee ASI 11/09, he participated in developing the BIM standard.

CONTENT

Prologue to the first edition 2021

Building Information Modelling (BIM) is the next big step for everyone involved in the construction process. The BIM method will play a central role in the entire execution process over the life cycle. Current BIM education still lags a little behind this development; it often focuses mainly on the application of BIM-enabled software. Functional BIM education is usually neglected. Especially in a BIM project, the responsibilities of the individual stakeholders and the proper communication between these stakeholders are extremely important. All participants must know these roles and tasks.

In the course of the BIM-Zert research project, researchers from four different leading universities (FH Salzburg-Kuchl, TU Wien, TU Graz, FH Kärnten Spittal/Drau) developed a standardised qualification and certification model for BIM in Austria together with practitioners experienced in openBIM, the Überbau Akademie and buildingSMART Austria. The recommendations from this research project are now being continued by buildingSMART Austria under the name BIMcert and correspond to the levels of the »Professional Certification« programme of buildingSMART International.

The idea for this book came from the meetings during the project and from the feedback of the participants in the first run. This book is dedicated to the functional openBIM training and describes all topics for the certification levels of the BIMcert training. We would like to thank all the colleagues who worked on the project for their support during the project and for the many ideas that also went into this book. We would like to thank Alexander Gerger for the careful design of the figures used in the book. Special thanks go to buildingSMART Austria, in particular Alfred Waschl, for their support in producing this essential basis for future BIM education.

Christoph Carl Eichler, Christian Schranz, Tina Krischmann,
Harald Urban, Markus Gratzl, Alexander Gerger

Vienna, September 2021

Prologue to the second edition 2023

Two years have passed since the first edition of the BIMcert Handbook. A lot has happened in that time. We received a lot of positive feedback on the first edition. For many, it has probably become an important textbook and reference work. The corrections and requests for additions have been beneficial. In addition, there have been some exciting new and further developments from the international buildingSMART community during this time. We wanted to include these in our book in the usual high quality. Therefore, we decided to invite guest authors in addition to our own extensions. We are delighted to have contributions from Léon van Berlo and Simon Fischer (on IDS), Jan Morten Loës and Frédéric Grand (on bSDD), and Thomas Glättli (on UCM). These contributions add expertise on new and important topics to the book.

We thank the guest authors for their valuable text contributions and all readers for their feedback and suggestions. We would like to thank Alexander Gerger for the careful typesetting of the book and the excellent design of the figures. Special thanks again to buildingSMART Austria, especially Alfred Waschl, for their support in producing this essential resource for BIM education.

Christoph Carl Eichler, Christian Schranz, Tina Krischmann, Harald Urban

Vienna, February 2023

1 Introduction

Building information modeling (BIM) represents the »next big step« for all those involved in the planning process in the construction industry. It is foreseeable that in a few years – as happened with the introduction of CAD in the 1990s – the entire handling process over the life cycle will adapt, with the BIM method taking on a central role. This will require appropriately qualified BIM training in the future. The verification of BIM knowledge must be regulated in internationally comparable quality standards for personal knowledge and competences. Therefore, buildingSMART International has developed a professional certification. This book deals with the topics of this professional certification.

1.1 Who is buildingSMART?

buildingSMART International (bSI) is an international not-for-profit organisation which is organised as an association. It was founded in the 1990s as the Industry Alliance for Interoperability (IAI), renamed to International Alliance for Interoperability shortly afterwards, and became buildingSMART in 2005. There are now more than 20 national organisations (local chapters) on four continents – e.g., buildingSMART Austria (bSAT), buildingSMART Germany (bSGer), or buildingSMART Switzerland (bSCH).

The core objective of buildingSMART (bS) is to improve the exchange of data and information between different software solutions in the construction industry. This is intended to optimise collaboration and the digital workflow. For this reason, buildingSMART has also been able to sign up all relevant software manufacturers as members. buildingSMART supports the importance of open (i.e., software-neutral) and interoperable solutions and stands for international, interoperable, open (data exchange) standards for BIM. These standards facilitate the creation of a comprehensive digital environment for the entire project and asset life cycle, providing significant benefits. buildingSMART aims to achieve their core objective through three core programs: Standards, Software Certification, and Membership Program.

As an independent association, buildingSMART develops its own standards for data exchange and collaboration. The best-known standards are the IFC and BCF, with the IFC having been published as an ISO standard in 2013 (ISO 16739). In addition, bSI also develops bSDDs for the description of objects and their attributes, MVDs for the definition of subsets of an IFC data model, IDMs for the description of information requirements, and IDS for the definition of information delivery specification. With these standardisations, bSI significantly supports the use of openBIM (BIM with open standards, see QR code). Software manufacturers can have their BIM-capable products certified by buildingSMART for the correct implementation of IFC. This certification guarantees a consistently high-quality transfer of data.

The buildingSMART Member Program promotes the understanding and use of openBIM standards and solutions. This includes the buildingSMART »Professional Certification« program.

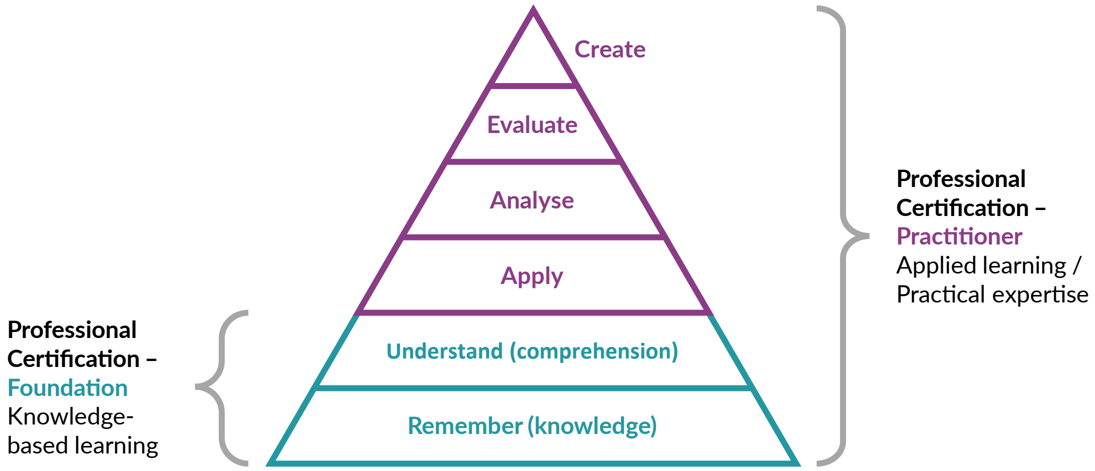
1.2 buildingSMART professional certification

BIM users can have their BIM knowledge certified via buildingSMART. For this purpose, buildingSMART has introduced the professional certification. The buildingSMART professional certification consists of two levels:

- Professional Certification – Foundation
- Professional Certification – Practitioner

The bSI »Professional Certification – Foundation« validates basic knowledge and the understanding of openBIM use in BIM projects.

The bSI »Professional Certification – Practitioner« verifies the knowledge of the practical use of openBIM over the entire BIM project from project initiation to handover of the building to the client. This certification level is not yet defined internationally.

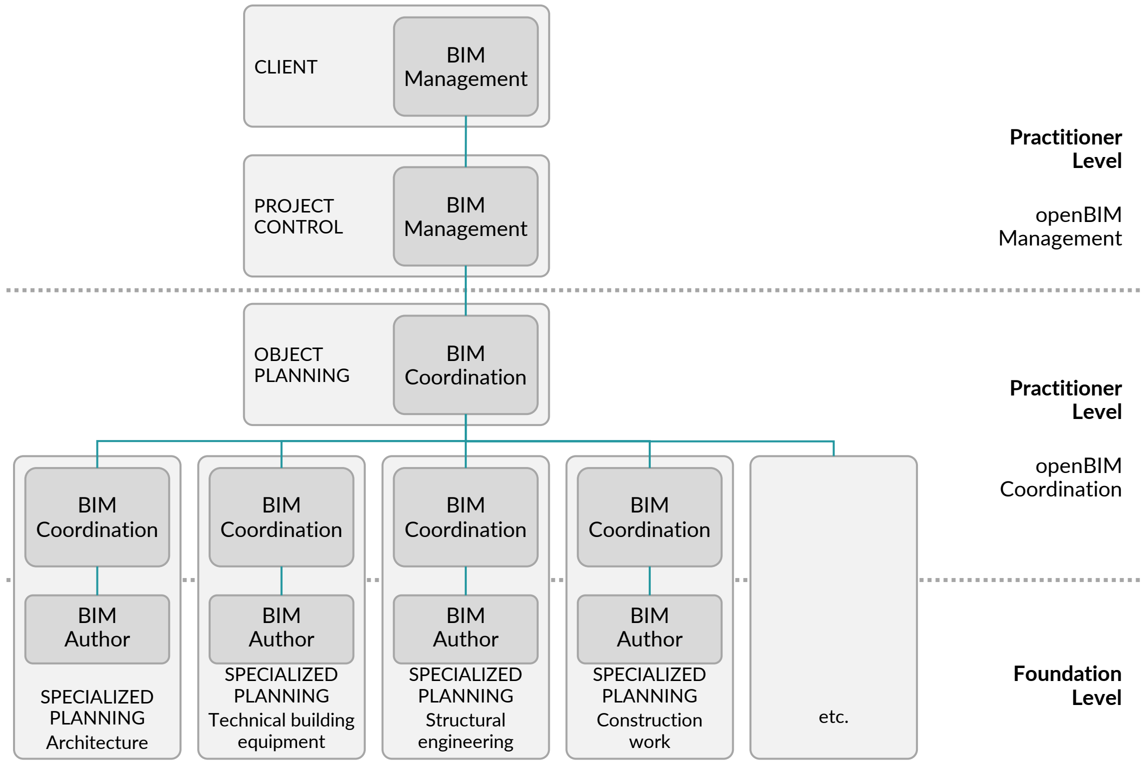


1.3 BIMcert – bSAT professional certification

In the research project BIM-Zert, buildingSMART Austria together with leading Austrian universities developed a standardised qualification and certification model for BIM in Austria, including these certification levels. The focus was on openBIM coordination and openBIM management. Since 2021, bSAT has been working with bSGer and the associated Certification SubCommittee of buildingSMART International to adapt the model for the international market.

The »Professional Certification« training takes place in topic-related lecture blocks focused. buildingSMART Austria has developed a recommended module structure for the »Professional Certification« training. This includes both the Foundation Level as well as the two areas of openBIM Coordination and openBIM Management at the Practitioner Level. As additional support for the Practitioner training, bSAT has also published regulations (EIR, BEP together with bSCH) and service specifications (LM.BIM).

bSAT Certified Trainer
buildingSMART Austria attaches particular importance to high-quality, functional openBIM training. This requires highly qualified trainers. For this reason, buildingSMART Austria uses certified trainers for the »Professional Certification« training. These trainers must renew their certification every three years to continue teaching in the »Professional Certification« courses. buildingSMART Austria checks the quality, depth, and scope of the openBIM knowledge in the certification process. This exanimation takes place before an international panel of experts consisting of members of the board of buildingSMART Austria and other national buildingSMART chapters (e.g., Germany, Switzerland, the Netherlands, Norway, Finland).



1.4 Structure and conventions

This book contains the topics for the buildingSMART »Professional Certification«. Chapters 1 and 2 deal with the basics of digitalisation, the tools and structures required for (open)BIM, the organisation including rules and regulations as well as standardisation. This knowledge is essential for the »Professional Certification – Foundation«.

Chapter 3 deepens the knowledge gained in Chapter 2 and explains important openBIM terms in detail. This chapter starts with an in-depth look at openBIM standards and a detailed explanation and description of the IFC data structure. Then it goes on to cover MVD, BCF, CDE, and LOIN. Finally, guest authors give an insight into IDS, bSDD, and UCM.

Chapter 4 is entirely dedicated to the use of openBIM. It provides a step-by-step explanation of the use of openBIM in each phase of a building's life cycle, from the project idea through design and construction. These chapters cover the »Professional Certification – Practitioner« topics for Austria. In addition, the published regulations and service specifications must be observed. These are listed in this book.

The appendix contains the curriculum proposed by bSAT for the »Professional Certification«. This can help the training partners (of bSAT) in planning the training. In addition, a guest author describes how to run a collaboration workshop.

The QR codes in this book either link to the source of the figure or to further information. In the electronic versions, the QR codes are clickable.

2 Basic knowledge

This chapter provides the basics for all those who want to take the buildingSMART »Professional Certification – Foundation« exam. It provides an easy introduction to openBIM. All basic terms of openBIM are explained here. Anyone involved in an openBIM project can thus rely on a common language with the same terms.

- Relevant für BIM novices, BIM practitioners and BIM experts who want to use the same term and all those who want to take the foundation exam, and
- no prior knowledge is required.

Important abbreviations are:

ADD	Addendum
AEC	Architecture, engineering, and construction
AECO	Architecture, engineering, construction, and operation
AIM	Asset Information Model
AIR	Asset Information Requirements
AR	Architecture
ASI	Austrian Standards International
BA	BIM author (model author)
BCF	BIM Collaboration Format
BEP	BIM exectuion plan
BIM-M	BIM-Management
BPMN	Business Process Modeling and Notation
bS	buildingSMART
bSAT	buildingSMART Austria
bSCH	buildingSMART Switzerland
bSDD	buildingSMART Data Dictionary
bSGer	buildingSMART Germany
bSI	buildingSMART International
CAD	Computer Aided Design
CDE	Common Data Environment
CEN	Comité Européen de Normalisation
CEN/TC	Comité Européen de Normalisation/Technical Committee
CV	Coordination View
DTV	Design Transfer View
DWG	Drawing
DXF	Drawing Interchange File Format
EIR	Employer's Information Requirements
EIR	Exchange Information Requirements
EN	European Norm
FM	Facility management
GC	General contractor
GIS	Geographic Information System
GUID	Globally unique identifier
HVAC	Heating, ventilation, and air-condition
IAI	Industry alliance for interoperability
IAI	International alliance for interoperability
IDM	Information Delivery Manual
IDS	Information Delivery Specification
IFC	Industry Foundation Classes
IFD	International Framework for Dictionaries
IPD	Integrated Project Delivery
ISO	International Organisation for Standardisation
LOD	Level of Development (outdated)
LOG	Level of Geometry
LOI	Level of Information
LOIN	Level of Information Need
MEP	Mechanical, electrical, and plumbing (incl. HVAC)
MVD	Model View Definition
OIR	Organisational Information Requirements
PAS	Publicly Available Spedification
PDF	Portable Document Format
PIM	Project Information Model
PIR	Project Information Requirements
Pset	Property Set
QA	Quality Assurance
QC	Quality Control
QR	Quick Response (QR code)
QV	Quantity View
RV	Reference View
STEP	Standard for Exchange of Product model data

TC	Technical Corrigendum
UCM	Use Case Management
XML	Extensible Markup Language

Abbreviations from German terms are:

AN	Contractor (Auftragnehmer)
AVA	Tendering, awarding, billing (Ausschreibung, Vergabe, Abrechnung)
BFK	BIM domain coordination (BIM-Fachkoordination)
BGK	BIM overall coordination (BIM-Gesamtkoordination)
BIM-ÖBA	BIM local construction supervision (BIM Örtliche Bauaufsicht)
BPL	BIM project management (BIM-Projektleitung)
BPS	BIM project controlling (BIM-Projektsteuerung)
DIN	German Institute for Standardisation (Deutsches Institut für Normung)
HOA	Fee regulations for architects (Honorarordnung für Architekten)
LM.BIM	Service specification (Leistungsmodelle.BIM)
LM.VM	Performance models & compensation models (Leistungsmodelle.Vergütungsmodelle)
ÖBA	Local construction supervision (Örtliche Bauaufsicht)
OHB	Organisational manual (Organisationshandbuch)
SIA	Swiss Society of Engineers and Architects (Schweizerischer Ingenieur- und Architektenverein)

2.1 Digitalisation basics

For a long time, the construction industry was one of the sectors least affected by digitalisation. In many areas and for a long time there was a high degree of process inefficiency, as project-oriented rather than process-oriented thinking has prevailed. As a result, communication, risk management, and contract implementation were in need of improvement. There is particularly high potential for optimisation in terms of wasted resources. In addition, the construction industry is very small-scale, specialised, and fragmented. Smaller companies often find it difficult to adapt to digital innovations. This has slowed down the digitalisation of the construction industry for a long time.

Digitalisation is opening up new optimisation potential for the construction industry. This so-called fourth industrial revolution is now gaining momentum in the construction industry. The benefits of digitalisation are gradually being recognised in the construction industry. They should help to solve the problems mentioned above. The benefits of digitalisation and digital models include the following:

- cost reduction,
- networking,
- information transparency,
- technical assistance,
- increased efficiency,
- improved communication and collaboration,
- flexibility,
- time savings,
- establishment of new business models,
- environmental friendliness (less waste of resources),
- increase in productivity,
- competitive advantages, and
- greater attractiveness of employers for new employees.

Good decision-making requires good data

BIM is considered a strong driver of digitalisation. ISO 19650 defines BIM as »*the use of a collaborative digital representation of an asset to support design, construction, and operation processes as a reliable basis for decision making*« (asset = building). The core of BIM is the digital building model, which contains the information in the form of geometries and alphanumericals. Thus, BIM provides an optimised, digital way of creating, exchanging, and maintaining digital building information. BIM promotes successful communication and collaboration between the parties involved in a construction project. This significantly supports quality assurance.

The possibility to visualise structures and their data using BIM can speed up the decision-making process. The digital exchange of project information reduces fragmented work processes and supports providing information at the right time. This can limit the amount of unstructured information and which improves the flow of information between stakeholders.

This is a huge advantage for construction professionals. The digital model brings together all the information provided by each stakeholder. Users of the digital model create, maintain, and use the model's geometry and information. Collaboration takes place in a common data environment (CDE), regardless of location. The main potential of CDE is the efficient communication, documentation, and reconciliation of information (data) from different sources. Since all components have attributes and these are stored in the system, quantities and costs can be planned and determined earlier and more accurately. The »accuracy« of a digital model is determined by the level of detail or depth of information requirements, e.g., Level of Information Need LOIN for the customer's information requirements (e.g., geometric and alphanumeric requirements, etc.) or Level of Geometry LOG for geometric requirements and Level of Information LOI for alphanumeric requirements. In the past, the Level of Development LOD of a model was also used.

A fundamental principle of BIM is the consistent exchange of data and information. Digital models support the consistency of data in the building database. There are modelling guidelines for this. Optimised information management improves collaboration, coordination, and model-based communication, helping to reduce or even avoid delays in the project process.

BIM benefits for clients and operators

The use of BIM offers many benefits not only to designers, but also to owners and operators of structures. The digital models support the transfer of consistent and digital project information from the structure to the operation. They help to manage common asset management tasks. Regular archiving of the model creates a long-term archive of the project (including its planning). This makes it possible to compare different planning stages and evaluate errors. By looking back on previous projects, operational requirements can be more efficiently incorporated into the planning of current projects. This significantly increases the scope for evaluation, reduces risk, and lowers the cost of developing and maintaining FM systems. Operational information can be fed into the model at a very early stage. Target/actual comparisons (GAP analyses) are easier. Operational requirements can be visualised and defined in advance of completion. This can help to predict better and reduce operating costs (maintenance and service costs, delivery times, energy consumption, etc.). The triggering events are already known from the data models. Shared and consistent information models reduce the time and cost of creating coordinated information. The models carry all relevant property information. This enables all important building information to be stored centrally and digitally, providing a better basis for FM decision-making.

It is important that data management is carried out and maintained conscientiously. Unstructured storage of collected project data leads to poor data management and increases processing time. Data must therefore be stored systematically and made available to all project partners. Conscientious data management, including versioning, is therefore important for effective communication and coordination. Digital building models created with BIM can represent and describe all information using objects and components. This integrates all aspects of the value chain throughout the lifecycle, avoids misunderstandings and improves the basis for decision-making.

BIM introduction in a company

There are many **benefits** to strategically implementing BIM in an organisation. Digital information models can carry almost all the data sets needed to complete and operate a construction project successfully. Conclusions and comparisons can be made at any stage. When internal processes/procedures are sensibly digitised, this leads to an increase in efficiency and consequently to cost savings (personnel costs, construction costs, operating costs). Good digitalisation requires an analysis of existing processes and possibly an adaptation of these processes to the possibilities of digital tools.

Automation can save effort. Systematic, software-based error checking means that conflicts are less likely to be overlooked. The visualisations lead to a better and faster understanding of the respective conflict. Conflicts can be resolved more quickly between domain planners. A high level of BIM competence also improves the image of an office.

The adoption of BIM is a holistic business decision. Hence, a BIM strategy is developed. This includes fundamental considerations about the value gained by introducing digital methods, the applications used, training concepts, and process definitions. The strategy is like a set of specifications. The desired added value can be improved project control, cost truth and transparency, adherence to schedules, high project quality within the set time and cost framework, streamlining internal processes, increased efficiency, cost savings, or improved communication.

The BIM strategy must be aligned with the organisation's objectives to ensure the investment is well spent. The measures take into account the current performance of the company, as well as its goals and other strategies. This is done by performing a gap analysis between the target and the actual to identify gaps. The necessary investments in people, processes, environment, data, and technology must be aligned with the objectives (more efficient allocation of resources). Only then should BIM implementation begin. Implementation is a strategic process, often requiring the old to give way to the new.

However, there are **challenges** to implementing BIM. There is often a temporary reduction in productivity at the beginning, depending on the initial requirements and objectives. The recruitment and training of competent staff must take place at the beginning of the implementation. This results in increased initial investment in training, hardware, and BIM-capable software. Similarly, the technical infrastructure requirements will be determined. These investments are likely to be recouped in the near future. Established contract and payment models will need to be redefined. Billing rules also need to be adapted to BIM software.

An organisation needs to know its own **BIM maturity level** to understand how it performs in relation to its competitors. Internal processes, resources and performance of staff and IT infrastructure, strategic goals, and objectives determine the BIM maturity level. There are several levels. At the lowest level of BIM maturity, BIM implementation is characterised by the absence of a strategy and the unsystematic use of BIM-capable software solutions. At the highest level of BIM maturity, the implementation strategy and organisational models are continuously reviewed and realigned, software solutions are used in a solution-oriented manner, and process changes are introduced proactively.

To do this, the company looks at its internal process management (workflows) and realistically assesses the existing skills of its staff. This provides a status quo and a basis for defining BIM objectives and an action plan.

A BIM implementation goes hand in hand with the increasing digitalisation of the company. As a result, data security becomes increasingly important. Effective data security measures include a data security plan, data encryption, and establishing an effective access rights structure on server environments or cloud-based platforms. These hierarchies must be constantly reviewed throughout their lifecycle to prevent unauthorised access, information loss and corruption.

Digitisation raises other legal issues – e.g., the question of liability and copyright for the content of the digital model or the rights of use for the data.

Steps toward digitalisation:

- Taking stock, examining the current situation, identifying opportunities,
- strategic concept and development of an action plan,
- tool selection,
- staff training, and
- ongoing optimisation and monitoring of progress.

2.2 Tools

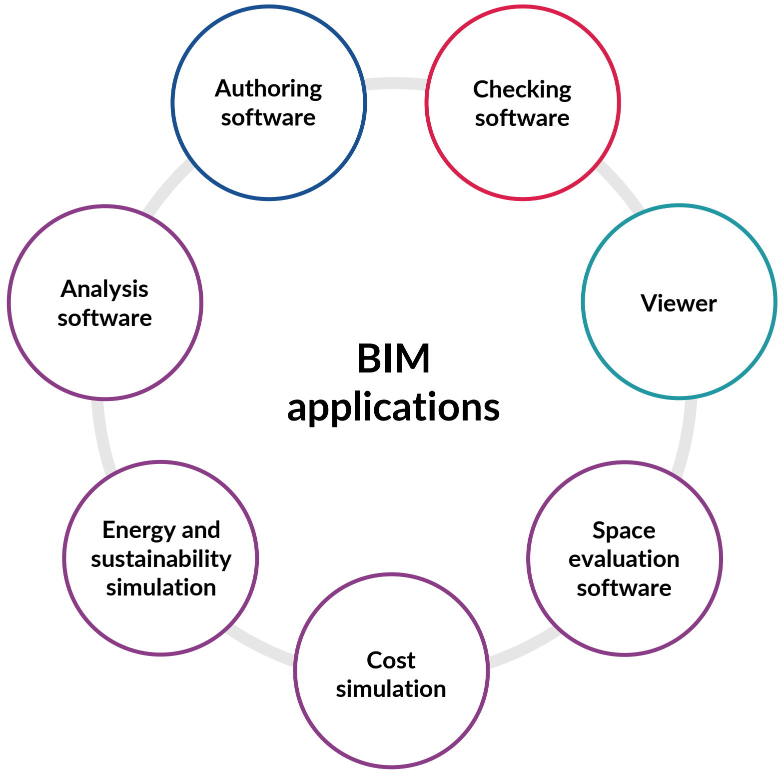
This category includes BIM software applications, collaboration platforms (Common Data Environment - CDE) and data structure tools.

2.2.1 BIM software applications

A variety of software products are used in BIM. These are referred to as BIM tools. The term »BIM software applications« refers to tools that are used to create, check, and evaluate model data. A BIM software application must meet the requirements and functionalities of the BIM method. Whether a software application already in use meets these conditions is shown by its status in the certification issued by buildingSMART (see QR code).

Certified BIM applications should be used in projects (status = completed). If noncertified BIM software applications are used, the requirements must be checked to ensure that the application is suitable. These requirements are defined in the regulations (EIR and BEP).

The following figure provides an overview of the different types of BIM software applications:



The main BIM software application is **authoring software**. This is where the model content is created according to the design, domain, and BIM organisational unit.

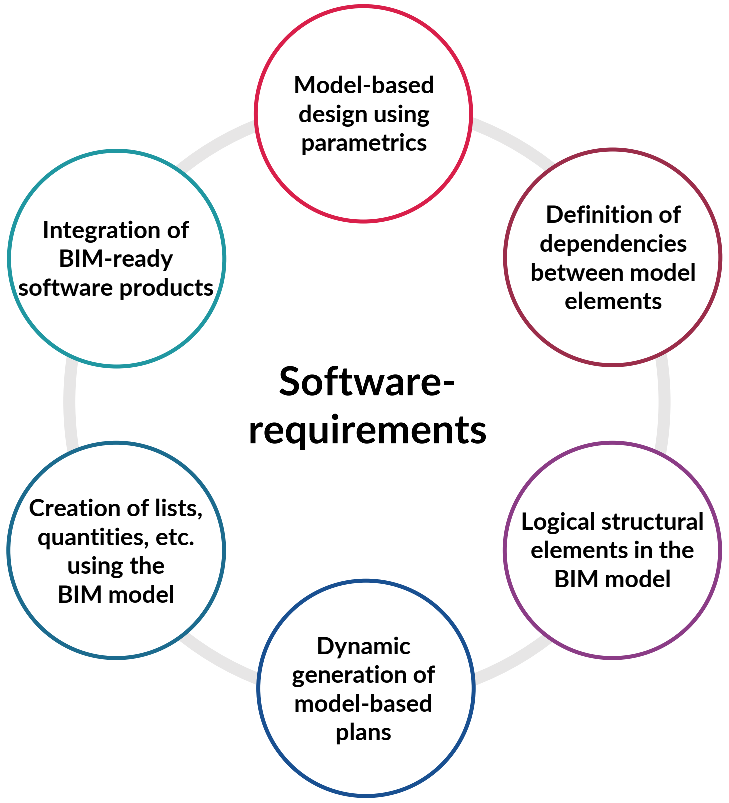
Checking software is a software application that checks but does not change model content. It is the most important application for quality management.

A **viewer** is software that only displays the content of models; it can neither check nor reuse model information.

The **other software applications** take model information (released and checked by checking software) and draw on this content for their own uses, calculations, and evaluations.

The choice of software application should always be well considered. Besides suitability for use in BIM (information found in the certification), the intended use, as well as acquisition and maintenance costs, should be taken into account. The following questions must be considered: Does the software manufacturer provide good support? Is good training available close to the office?

The most important requirements for software applications (especially with regard to interoperability) are summarised in the following figure:



A BIM software application must therefore
- be able to map, derive, and communicate model content according to the IFC data structure/interface (geometric and alphanumeric),
- be able to establish the dependencies of model elements on each other (e.g., what floor a wall belongs to or windows in a wall),
- be able to map and read logical structural elements (e.g., MEP systems),
- dynamically derive plans (mainly in PDF and DWG/DXF formats),
- be able to create evaluation lists of model content, and
- have the functionality to integrate with all other BIM-capable software applications and BIM tools that are not from the same software group.

2.2.2 Collaboration platforms

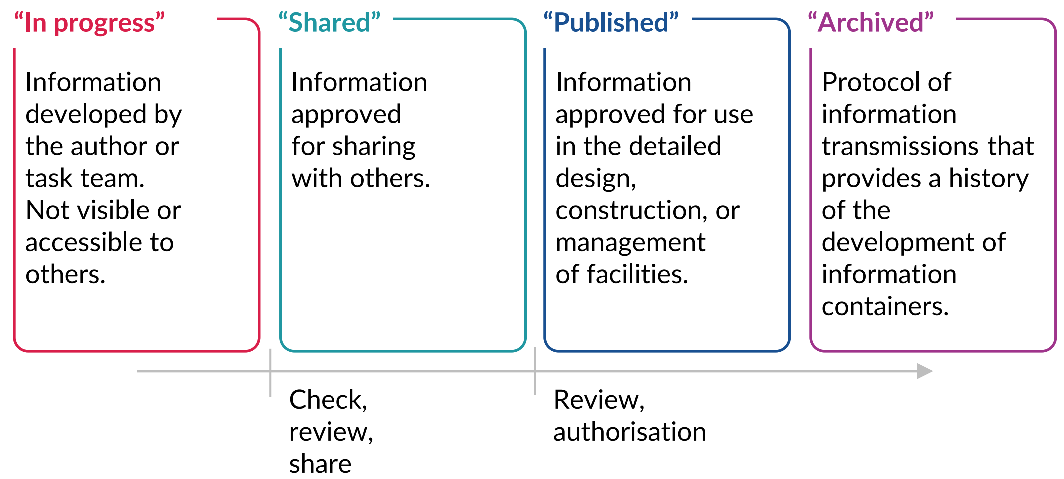
Collaboration platforms are BIM tools that offer web-based services for handling collaboration in projects. They are used to centrally handle project-related communication and data exchange. They offer a common data environment (CDE). Their major advantage lies in the uniform structuring of project handling (if required, also across projects).

CDEs are therefore used for information management of projects and properties. As central project spaces for storing and exchanging all project information with all project participants, they consolidate all project knowledge and make it quickly available. They offer controlled access (person-dependent, role-specific) to project information, clearly defined exchange processes, and a clearly defined document and model status. Changes and revisions are recorded. This ensures transparency of communication and improves the exchange of information. All the collaborative activities required to create the PIM and AIM take place within the CDE.

ISO 19650 describes the concept of a CDE. According to ISO 19650, a CDE should support three different information container states:
- WORK IN PROGRESS
- SHARED
- PUBLISHED

In addition, there should be an archive container (ARCHIVED) that records all the operations of the other information containers in the form of a log (journal of released and published information containers). This allows the development of a combined and collaborative information model.

Furthermore, comprehensive data security must be provided and information exchanges must be verified by control authorities. During information transfer, the data must be versioned and logged.



Examples of typical collaboration platforms currently used in projects for higher-level collaboration are Aconex from Oracle, and Conclude CDE and tpCDE from Thinkproject. For collaboration within a domain, integrated collaboration platforms are sometimes used, such as Autodesk BIM 360 or Graphisoft BIMcloud.

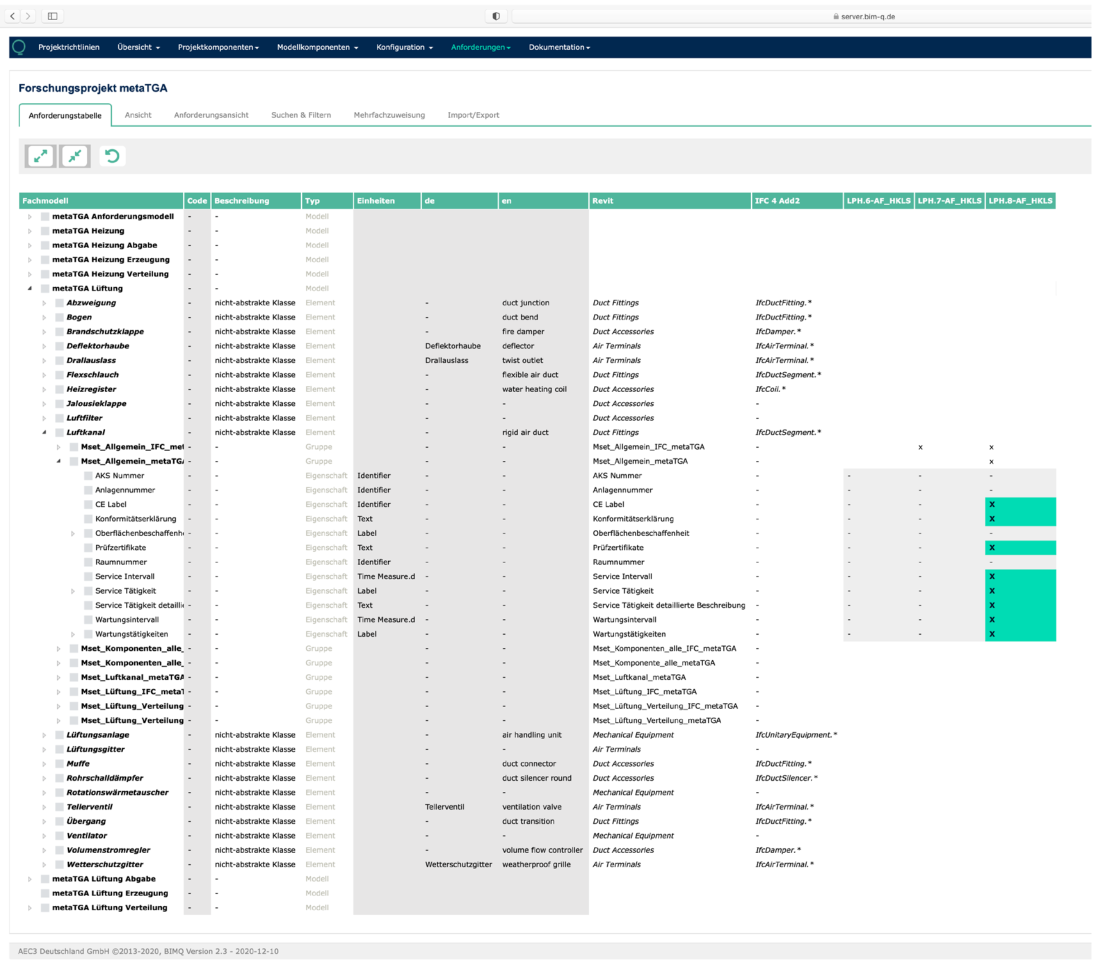
2.2.3 Data structure tool

Data structure tools are another type of BIM tool. They are web-based services for the creation and modification of individual data structures and of the levels of detail based on them. They offer central moderation and integrated distribution to various channels (BIM software applications, BIM rulebooks, etc.), thereby minimising the respective individual adaptation effort.

Data structure tools support the definition of the EIR and the creation of projectspecific BIM guides. They allow the direct derivation of the checking rules for the BIM checking software. This improves the quality management and quality control of the BIM models.

A typical example of a current data structure tool is BIM-Q from AEC3 GmbH. This web application allows

- the creation of individual data structures and the assignment of content to different project phases or use cases,
- the structuring of associated mappings of external data structures (e.g., IFC2x3, IFC4, IFC4.1),
- the creation of corresponding mappings of program-specific data structures (e.g., Allplan, ARCHICAD, ProVi, Revit, Vectorworks) and the output of the respective configuration files,
- the export/reimport of all database content into XLS files for further processing in table editing programs,
- the automatic creation of documents describing the data structure specifications (LOI annex of EIR), and
- the automatic creation of bases for model-checking routines in BIM checking software.



2.3 Structure/data schema

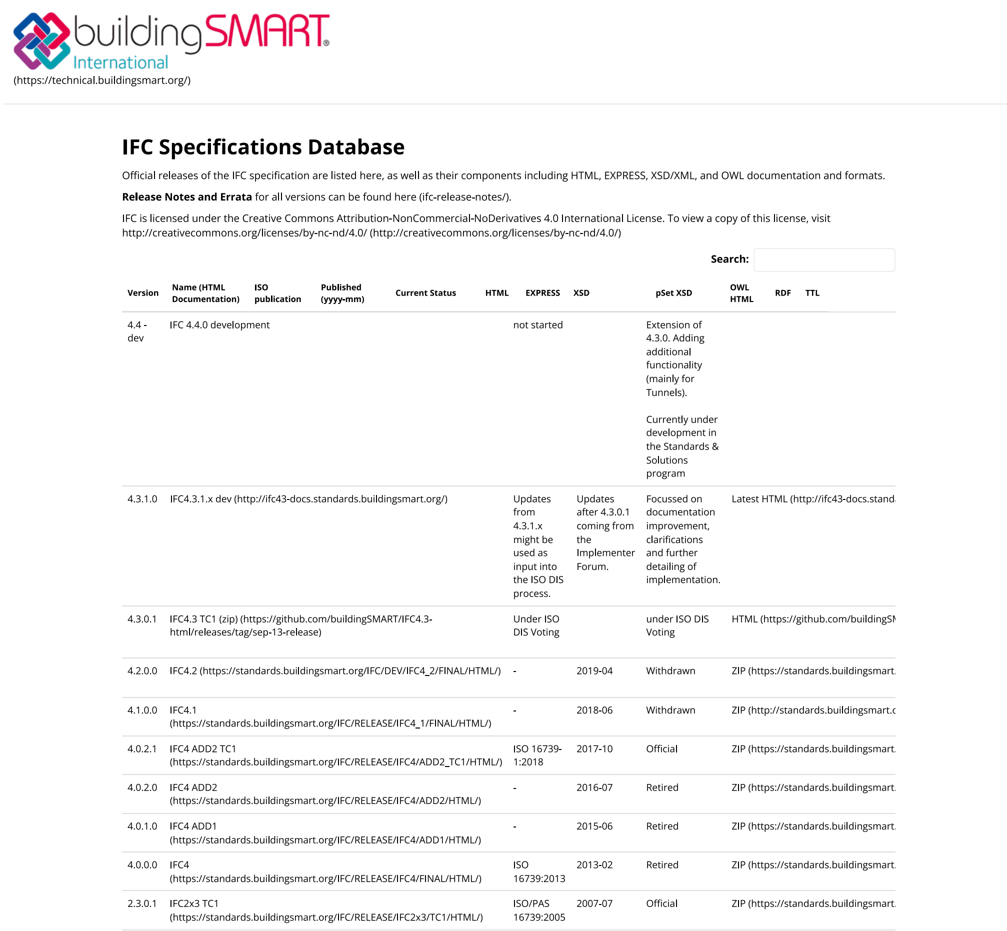
This section provides an introduction to the IFC data structure, the bSDD platform, BCF comments, and DataSheets.

2.3.1 IFC data structure

IFC stands for industry foundation classes. It is an open data format (data schema) for building information based on the STEP Physical File (SPF, STEP = Standard for the Exchange of Product Model Data). Another data format is XML. Since 1995, buildingSMART International has been developing IFC as part of the openBIM standard. Since 2013 (publication of IFC4), IFC is an official ISO standard with ISO 16739 and is regularly updated with this standard. buildingSMART also recommends using IFC for referencing and archiving models.

With the current version IFC4, all essential trades of building construction can be mapped in the data structure. For the upcoming version IFC5, it is planned to integrate the infrastructure areas road, rail, bridge, and tunnel and the associated routing (IfcAlignment).

IFC ensures the vendor-neutral transfer of building information. Therefore, all known national BIM standards refer to IFC. The following figures shows several previous versions of IFC.

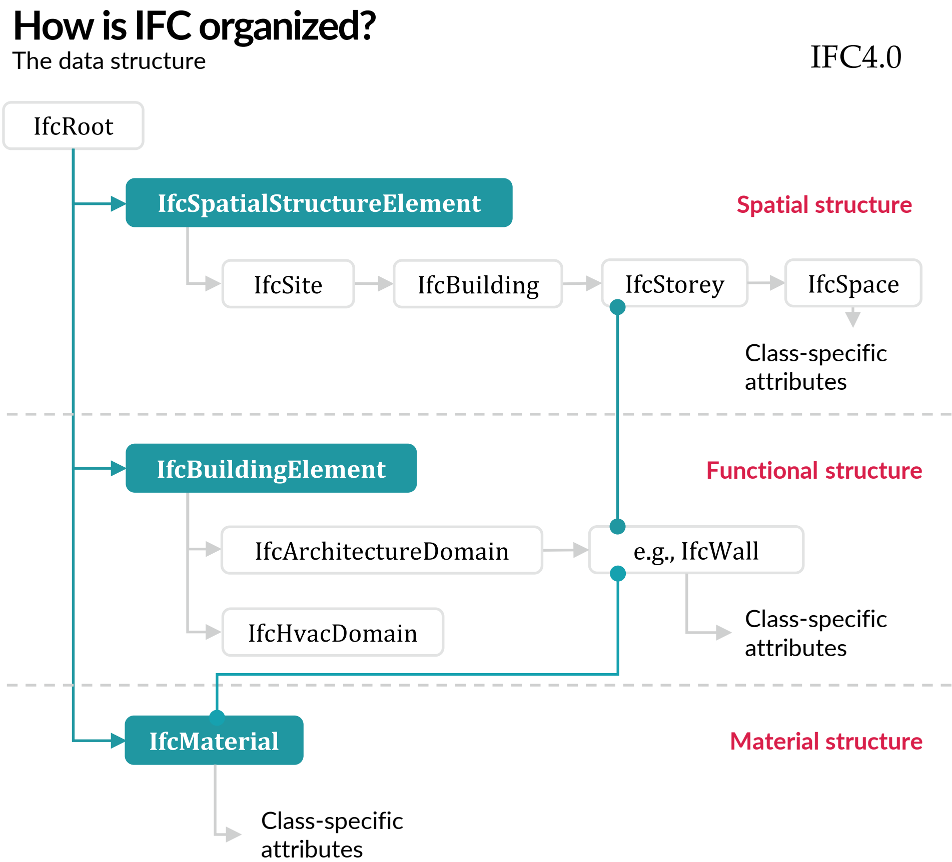


IFC are integrated in all common BIM software applications. Software certification by buildingSMART International ensures consistently high transmission quality. The software manufacturers must complete the associated certification process for each IFC version.

The IFC specification uses three structures: location structure, functional structure, and material structure.

The location structure defines the spatial structure of a building in IFC. It declares building sites, structures located on them, floors located in them, as well as the rooms present on a floor.

Buildings are mapped within the functional structure by breaking them down into individual functional element classes: e.g., walls, ceilings, columns, doors, or windows. Each element (element instance) is given a unique identifier (GUID). The BIM software application generates this unique declaration. Each functional element class is optimised for the mapping of its functional domain. Therefore, it carries a standardised basic set of characteristics for describing relevant properties (parameters) as well as its typical geometry (attributes). The characteristics are organised into groups (so-called Psets = property sets). Each element class carries a typical Pset which carries the most essential characteristics. This Pset is designated with the suffix »Common«, e.g., Pset_WallCommon or Pset_DoorCommon. Psets can also apply to several element classes at once, e.g., Pset_Warranty.



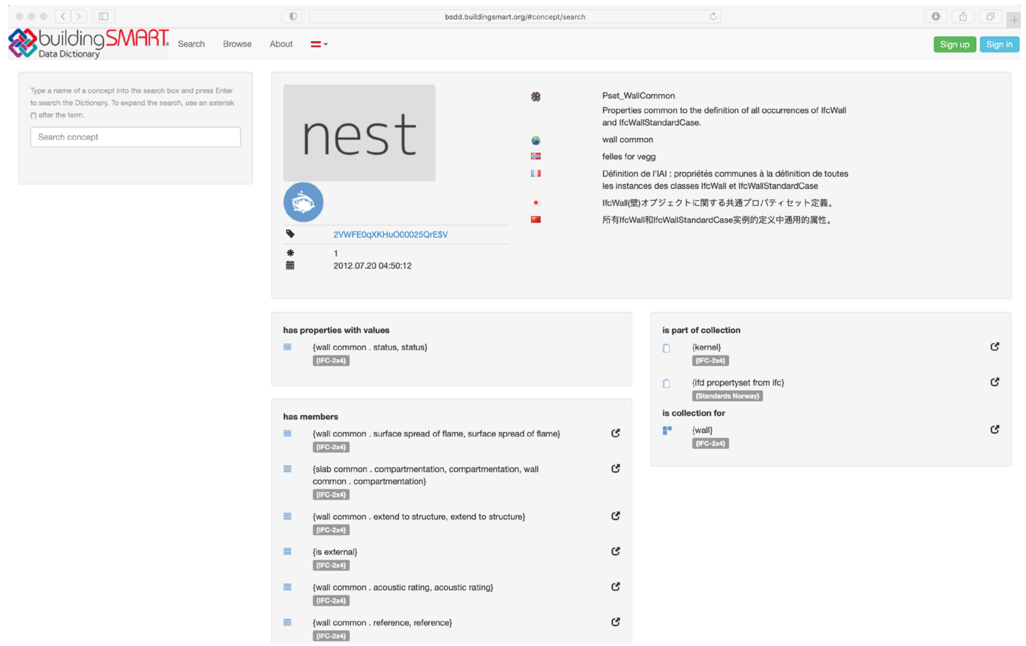
All functional elements are linked to floors and are thus also associated with a building. In addition to alphanumeric (object properties, attributes, parameters and characteristics) and geometric information, an IFC file also contains object relationships.

Besides the location structure and the functional structure there is also a material structure in the IFC data structure used for declaring material-related properties. Unfortunately, this is implemented very heterogeneously in the BIM software applications currently available on the market. This should change in the medium term with the introduction of ISO 23386. This standard on DataSheets regulates the interaction of building information with material and product information. Therefore, a change in the material data structure is to be expected with the release of IFC5 – and after the release of IFC5 this change is to be implemented in BIM software applications.

2.3.2 bSDD platform

bSDD stands for buildingSMART Data Dictionary. It is a web-based service for the creation and consolidation of individual data structure supplements (ontologies) based on ISO 12006-3. The associated possibility of providing multilingualism is seen as an advantage. bSDD is not a standard; it is owned by buildingSMART. It is based on the open IFD (International Framework for Dictionaries) standard.

The bSDD platform is a library of objects and their attributes. Each content stored on the bSDD platform is given an identifier/label (regardless of language) and is incorporated into a classification system. These classification requirements can be transferred to model elements. For this purpose, the bSDD platform assigns a unique identifier (bSDD GUID). This allows objects and their attributes (parameters, characteristics, allowed values, units, translations) to be uniquely identified.



The bSDD platform makes it possible to create individual element classes, individual psets, individual characteristics or even individual values of a characteristic as content. The person/institution that created (declared) the content is responsible for each stored content. Other persons/institutions can add their translations to such a declaration.

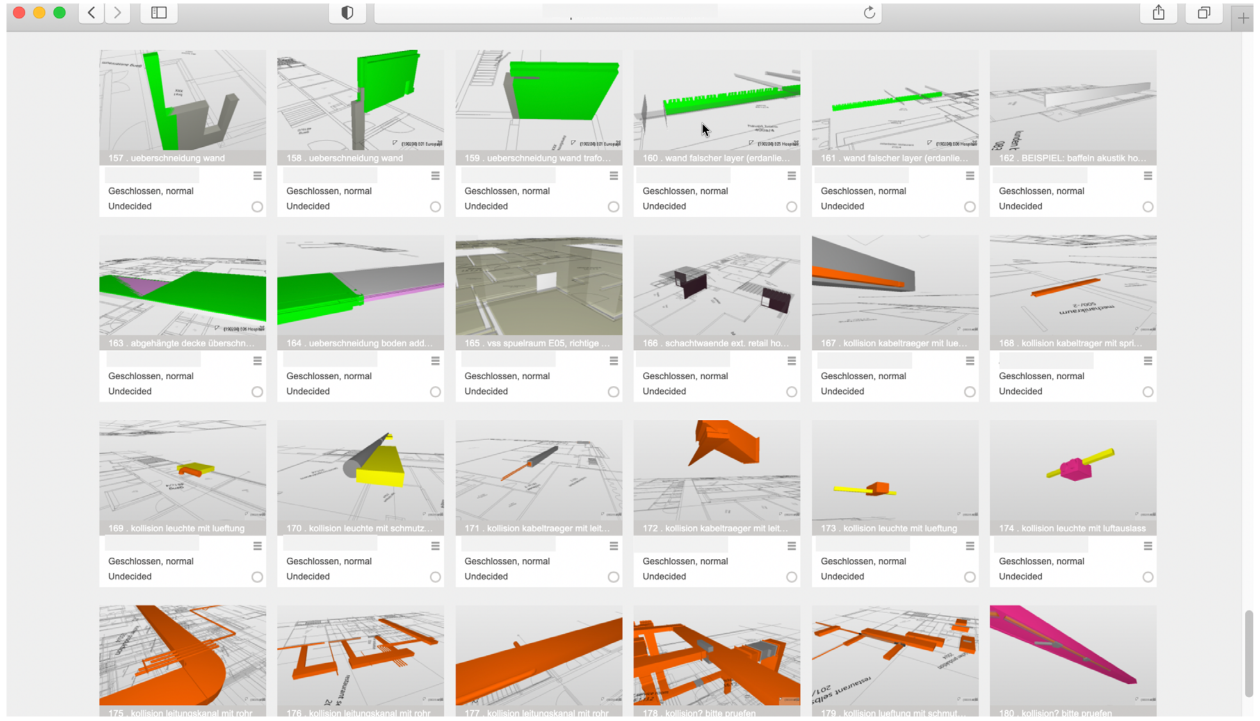
2.3.3 BCF comments

BCF stands for BIM Collaboration Format and is an open data format for model-based communication. Introduced in 2009 by Solibri Inc. and Tekla Corporation, it was subsequently adopted by buildingSMART International as part of the openBIM standard.

BCF is used to simplify the exchange of information during the work process between different software products (based on the IFC exchange format), thus enabling traceable communication of problems or changes. The current version BCF 2.1 allows the transfer of

- model-related comments (so-called issues),
- the affected elements in the model (via the object GUIDs), and
- reproducible screen clippings

between different BIM applications. This model-based communication improves coordination. Thus, information about problems in the model (problem report and status), their location, viewing direction, component, remarks, user, time, or even changes in the IFC data model can be exchanged in a targeted manner. The goal is to transfer the relevant information and not the entire model. The scope of the functions for the transfer of properties between different models will be expanded in the next versions of BCF.



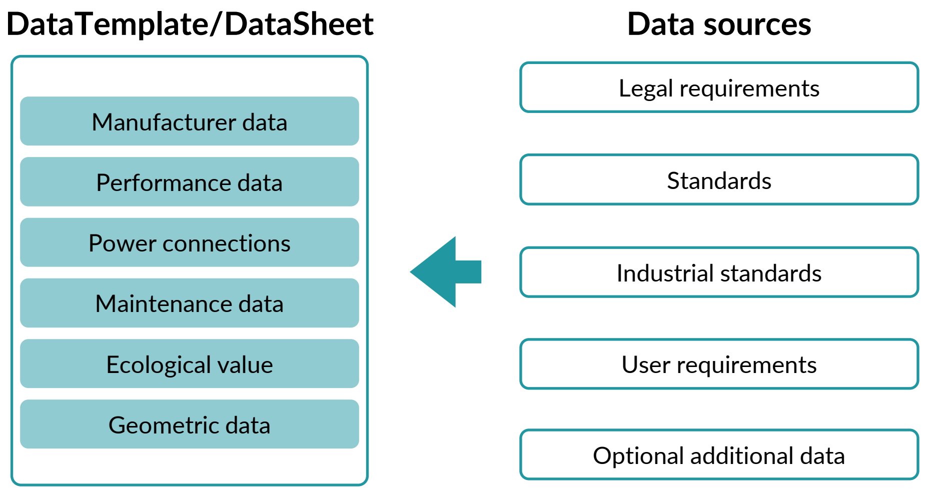
BCF is integrated in all common BIM applications. In some cases, special additional modules (AddOns) are required to extend the range of functions.

2.3.4 DataSheets

DataSheets is a symbolic term for Digital Construction Products. It is a container-based technology for the digital representation of the interaction between harmonised European product standards (CPR - Construction Products Regulation) and Environmental Product Declarations, which will be normatively regulated by ISO 23386 from 2020.

The structure, composition, and content of the data sheets in different construction product structures are based on the specifications of the harmonised product standards. This conformance is essential because all industry approval processes are based on these specifications. This is the only way to ensure the complete information in DataSheets for productive use. There are also plans to integrate a building product's sustainability information (EPD - Environmental Product Declaration) according to ISO 22057 into DataSheets.

A distinction is made between generic (product-neutral) DataTemplates and specific (product-related) DataSheets. This makes it possible to apply processes that are compliant with procurement law. In the planning phase, generic DataTemplates can be used to precisely describe the requirements for materials or products, which can then be unambiguously interpreted by a bidder in the course of the tendering process and responded to by specific DataSheets with information on specific products. The processing of this information can be largely automated, since DataSheets are fully machine-readable. This advantage, combined with the automated collection of masses and quantities from the digital models, will change the interaction between planning, execution, industry, and logistics – the construction of a continuous data chain to building products will become a reality.



The interaction between Data Templates/Data Sheets and IFC-based digital models is governed by ISO 23387. This refers to the bSDD when declaring features of a DataTemplate/DataSheet. In this way, features of different products are coordinated and not redundantly created. The transfer of a DataTemplate/DataSheet, together with its bSDD-based features, can be file-based (via an IFC file) or web-service-based (via an API connection). As this is a recent development, integrating DataTemplates/DataSheets into BIM applications is still in preparation.

2.4 Organisation

This section covers the BIM-relevant organisational topics of roles and service specifications, BIM rulebooks, collaboration in openBIM, and the IDM methodology including MVDs.

2.4.1 Roles and service specifications (LM.BIM)

The conventional service specifications (e.g., HOA, LM.VM) currently do not contain any specific information regarding the basic services for the proper execution of a project with regard to BIM. Therefore, for BIM projects a definition of separate roles and service specifications (= service models LM.BIM) is necessary. However, the roles (and also BIM organisational units) in the project must refer directly to BIM tasks and BIM services in order to retrieve them. The use of BIM performance models is not mandatory but recommended.

Established BIM service specifications (LM.BIM) are currently freely available from buildingSMART Austria (see QR code). They are already in use in numerous BIM pilot projects of private and public clients. The first version of the specifications was made available by buildingSMART Austria in 2019. Based on project experience and further developments, an updated version has been published (LM.BIM 2022).

The main objective of LM.BIM is to create a uniform understanding between the client and the contractor of the scope of services to be provided

- for the basic interaction of the services,
- for the allocation of services to the respective BIM organisational units (roles),
- for the service to be provided by each BIM organisational unit (role), and
- for the general differentiation from existing, conventional services.

The medium-term goal of unified LM.BIM is the creation of associated standard terms of compensation.

The LM.BIM flow into the BEP via the EIR. They form the basis for the content of the topics of project management and implementation in the individual project phases (services of the client and contractor). A service specification always includes the classification of the respective organisational unit in the overall structure, the description of the general and cross-project-phase services, and the project-phase-related services.

The LM.BIM can be customised on a project-by-project basis. This is done to

- increase the potential pool of bidders by lowering the requirements,
- reduce bid prices through prophylactic reduction of the scope of the services to be provided, and
- modify responsibilities due to changed project constellations.

The LM.BIM describe the roles and services of the BIM organisational units. In Austria, these are:

BPL – BIM project management (client): qualification at the level of the owner. The *BPL* is responsible for the general definition of the framework of a project and the service specifications used by the respective actors, as well as for the enforcement of the client's requirements for the data structure used in the project. The *BPL* is responsible for the preparation of the EIR. The *BPL* prepares the model BEP based on the EIR in accordance with the buildingSMART Austria service specifications (LM.BIM 2022).

BPS – BIM project controlling (client): qualification at the project controlling level. It represents the interests of the client in the concrete specification and operational implementation of a BIM project within the framework of the BIM project management specifications. The *BPS* oversees the creation and maintenance of the BEP and approves it when the specifications and objectives of the client are met in accordance with EIR regulations.

According to the previous buildingSMART Austria service specifications (LM.BIM 2019), the *BPS* can take responsibility for creating and developing the BEP. With the LM.BIM 2022, this responsibility has been transferred to the *BGK*.

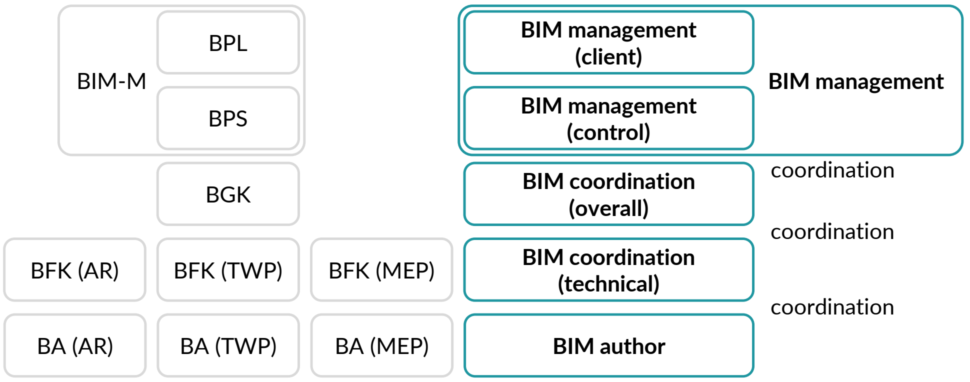
BIM-M - BIM Management (client): According to the new service description of buildingSMART Austria (LM.BIM 2022), it is possible to replace the two organisational units, *BPL* and *BPS*, with the BIM Management. Accordingly, all tasks of both organisational units will be transferred to the responsibility of the BIM-M.

Note: The BIM-M does not supplement the information in this handbook on the organisational units BPL and BPS; the responsibilities and tasks are part of the BIM-M.

BGK – BIM overall coordination (BIM-Gesamtkoordination) (contractor): coordinates and verifies the interdisciplinary BIM content of the parties involved in the planning process based on the specifications of the BIM project management. It is responsible for the coordination model and monitors the implementation of the specified technical coordination tasks. The *BGK* is responsible for preparing the BEP according to the specifications of buildingSMART Austria (LM.BIM 2022). In terms of coordination, the *BGK* is closer to the project participants on the contractor side and therefore has a better insight into the current needs of the project participants on the contractor side. For this reason, the *BGK* is responsible for preparing and adapting the BEP during the project. The *BGK* is the primary point of contact for digital design for the BIM project management, which monitors and approves the BEP during its creation and ongoing adaptation.

BFK – BIM domain coordination (BIM-Fachkoordination) (contractor): verifies the openBIM content of its own domain in proactive coordination with the other *BFK*. It is responsible, among other things, for providing the *BGK* with the domain model in verified form (including verification reports), managing BCF comments relating to itself, ensuring the conformity of the domain model and planning documents, and carrying out model-based evaluations (e.g., for cost determination) from its own domain model.

The corresponding BIM organisational units coordinate among each other (see figure).



Note: Some standards define the BIM organisational unit »BIM user«. This describes a project member who uses the models only to obtain information and does not add any data or information to the models.

The aim of the organisational structure is to clearly define contact persons, to show clear decision-making paths and a clear distribution of tasks.

To allow cooperation, the assessment of the BIM competence of all project participants involved over the life cycle of a project is required. The client must analyze the BIM competence (qualification) of the project participants. The qualification of the organisational units should be confirmed at the beginning of the project by verifying competencies.

The *BPS* determines this via

- questionnaires,
- proof of participation in training (organisational training and for software applications), and/or
- the specification of BIM project experience (across several project phases), i.e., project-specific assessments.

This helps to identify potential competence deficits and define training requirements. Only then can project responsibilities be defined.

The previous service specifications of buildingSMART Austria from 2019 can still be used in projects, but it is recommended to use the current LM.BIM 2022, as these are more compatible with the traditional service specifications (such as HOA, HO-PS, RVS or LM.VM) and contain empirical values gained from numerous openBIM projects. The previous service specifications listed the organisational units of BIM creation and BIM ÖBA:
BA - BIM author (contractor): acts as the modeller of discipline-related model content.
BIM-ÖBA **- BIM local construction supervision** (contractor): implements the specifications and organises the corresponding technical setup on-site.

2.4.2 BIM rules and regulations (EIR, BEP)

BIM rules and regulations form the basis of BIM projects. BIM rulebooks explain the relevant objectives of the client, the requirements for the project participants, and the procedures for the successful implementation of these requirements. They also specify any supplements to the common project manuals, e.g., the OHB or project manual.

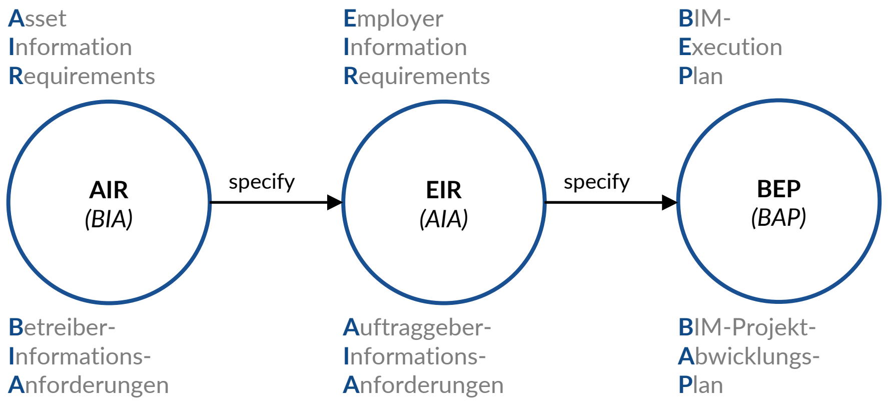
The application of BIM rules and regulations is strongly recommended for projects of any size, even though it is not (yet) mandatory. The BIM rules and regulations provide a clear regulation of the project organisation, the project objectives, the specifications for project implementation, project management, the definition of cooperation, and quality assurance for BIM projects. These regulations are mostly missing in standard project manuals. BIM rulebooks (such as EIR) also help clients identify what information is necessary to achieve their project goals.

The currently established and freely available BIM rulebooks are the EIR and the BEP (see QR codes) released by bSAT/bSCH (2020). The individual BIM rules and regulations are:

AIR – asset information requirement: The AIR defines the operator's long-term data structure and detail requirements based on data management. It determines the valid sources of information for the base estimation. The AIR is created independently of the project by the operator's BIM management and serves as a company-wide basis for the creation of project-specific EIR.

EIR – exchange information requirements: The EIR is the concrete description of the client's information needs and is therefore described as a requirement for the contractor. According to ISO 19650, it defines the managerial, commercial, and technical aspects of project information production (e.g., information standards). It serves as the basis for the BEP in the relevant project. In particular, the EIR contains the BIM requirements, BIM processes, BIM deliverables, standards to be met and BIM applications to achieve the client's BIM objectives.

BEP – BIM execution plan: The BEP is a policy document that defines the basis of a BIM-based collaboration. It defines the organisational structures and responsibilities. Roles and responsibilities/accountabilities can be assigned in a matrix. The BEP provides the framework for the BIM services and defines the processes/workflows and the requirements for the collaboration of the individual participants (e.g., responsibilities). The models and processes are standardised in terms of structures, elements, and information. The BEP also specifies the project-related characteristics, defines the level of information and detail, and their qualities. It is prepared by the project team and updated throughout the project. A well-prepared BEP improves the planning process and communication within the project team. The BEP should be part of the contract between the client and the project participants. The EIR, on the one hand, and a possibly provided model BEP, on the other hand, serve as the client's guidelines for the BEP.



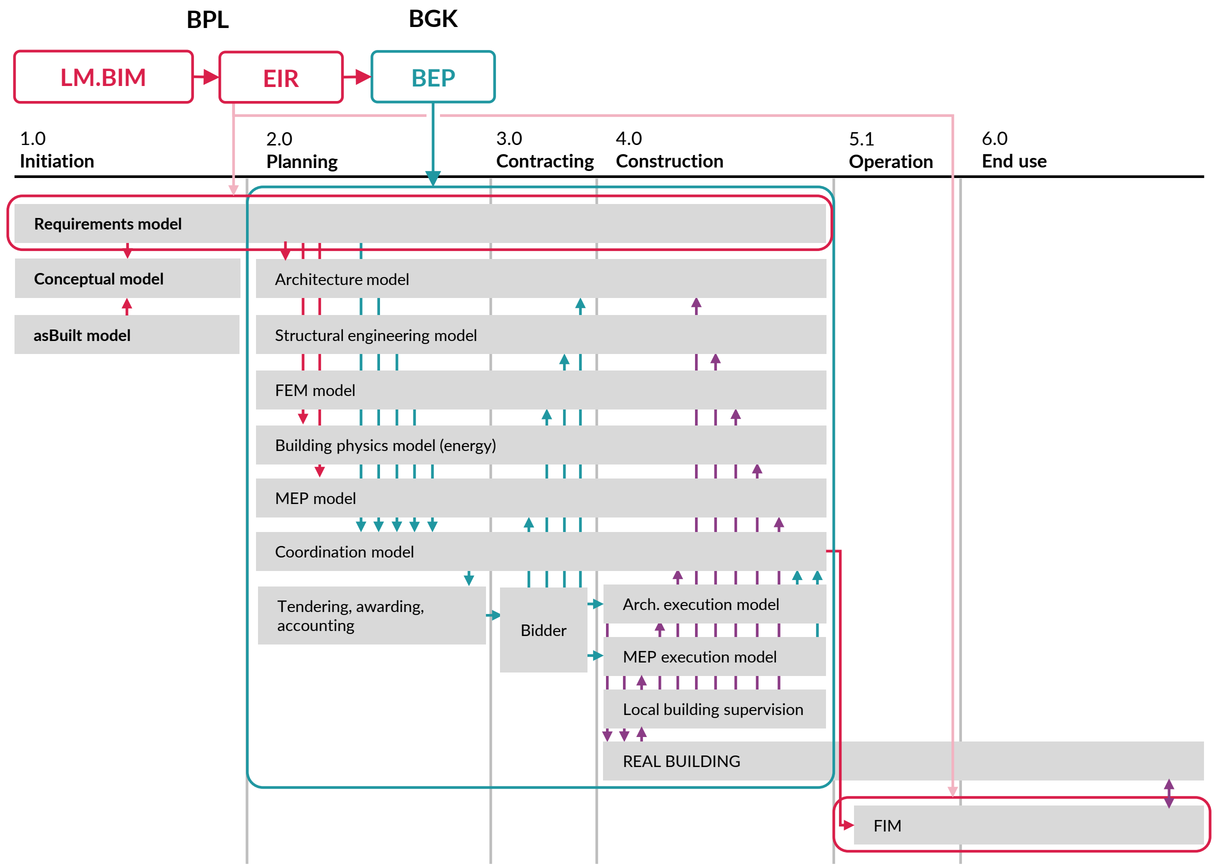
Section 2.5 contains further information on standardised information requirements according to ISO 19650, Parts 1, 2, and 3.

Hierarchically, the AIR are hierarchically above the EIR – its requirements feed into the EIR. The EIR specify the client's information requirements beyond the AIR. Based on the EIR, the BEP also incorporates the requirements of the AIR and serves as a concrete set of project rules. The BEP should be applied to BIM projects from the start of design to the completion of construction or handover to service and updated as the project progresses.

The topics of the EIR and BEP include:

- **project information:** summary of the client's content specifications (e.g., times/milestones for information transfer),
- **general requirements:** summary of the normative specifications of the client (e.g., standards and guidelines to be adhered to, required file formats including versioning),
- **model-specific specifications:** definition of model structure and intended development stages,
- **project organisation:** definition of the organisational levels and associated service specifications (responsibilities),
- **use cases:** specifications for the use of model data, such as uniform model checking or cost determination, and
- **annexes:** in-depth description of individual aspects (e.g., technical guidelines such as the definitions of LOG and LOI).

This needs to be taken into account: The EIR defines the content of the subject areas, and the BEP formulates these specifications. For example, the BEP (as per ISO 19650) also contains the assignment of names/competencies to the individual roles and the information delivery strategy for the process and compliance with the required exchange information. The BEP also defines quality control. At the beginning of the project, a colloquium on the EIR/BEP should be held with all key project participants. At this meeting, the content and scope of the tasks will be explained and agreed upon. Such a colloquium promotes successful cooperation in the project. The *BPS* can also use the colloquium to check the participants' level of knowledge on the topics of an openBIM project.

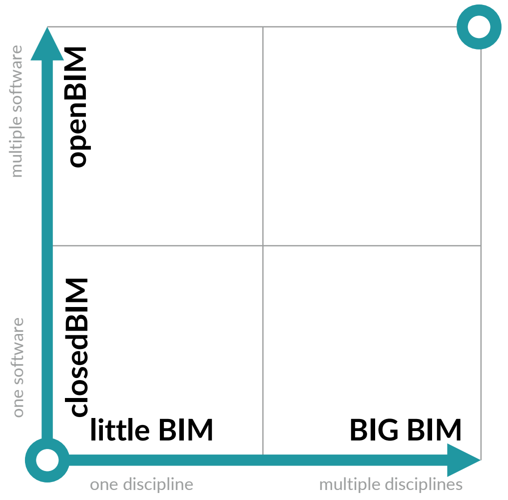


2.4.3 openBIM collaboration

The advantages of the BIM method should be exploited fully, not only technically but also structurally. Therefore, the use of the openBIM method is recommended for all projects. In terms of implementation and collaboration, the advantages are as follows:

- software independence and freedom of choice for software applications for all project participants; therefore, no competitive disadvantage regarding software applications,
- long-term usability of model data (readable text files, sustainability through ISO certification of IFC and the IDM), and
- autarky of software-specific model information (transparency).

The development stages of BIM provide a clear classification in this respect:



little BIM: BIM island, BIM only used in isolated disciplines/domains

BIG BIM: BIM-Integration in all disciplines/domains

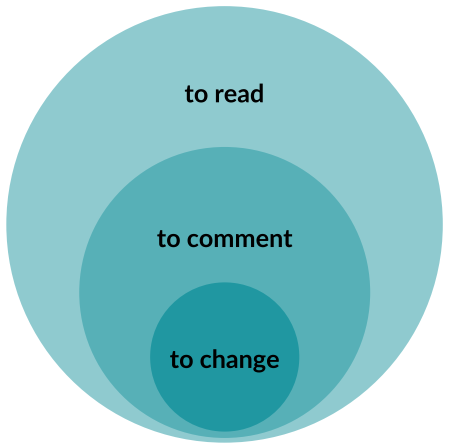
closedBIM: closed solution, use of one software (family)

openBIM: open solution, interchangeability across different BIM-capable software applications

The free choice of software supports the use of the most suitable software for the respective task (best practice).

The application of the openBIM method is also promoted by national standardisation. For example, in Austria ÖNORM A 6241-2 lays the foundations for a comprehensive, uniform, product-neutral, and systematised exchange of graphical data and the associated factual data based on IFC and bSDD.

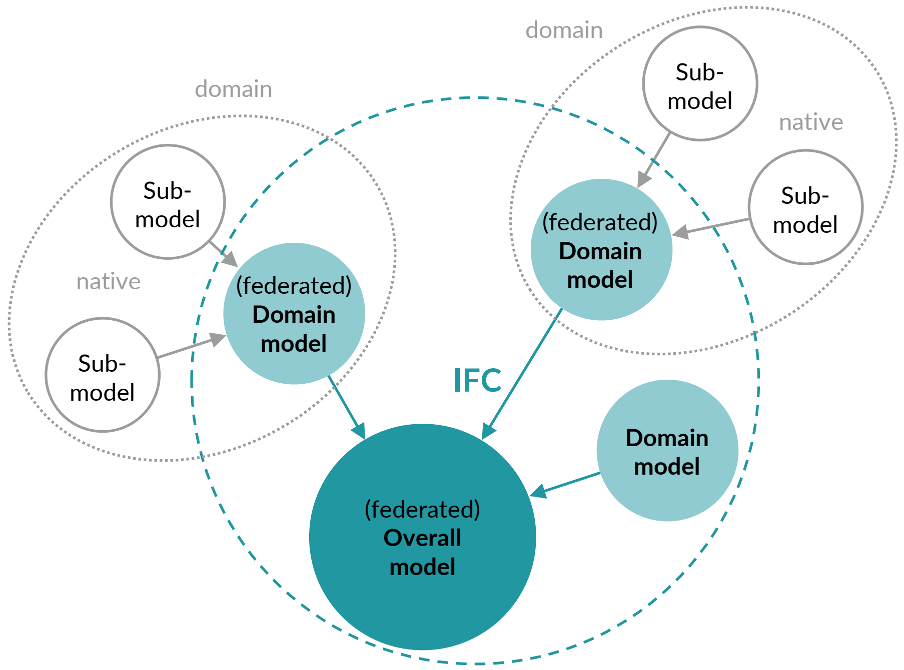
The BEP regulates the form of structured cooperation by specifying the interfaces, including the MVD. The use of by buildingSMART-certified software is a prerequisite. An essential aspect of data exchange is interoperability: the secure transfer of the object information from the models must be guaranteed.



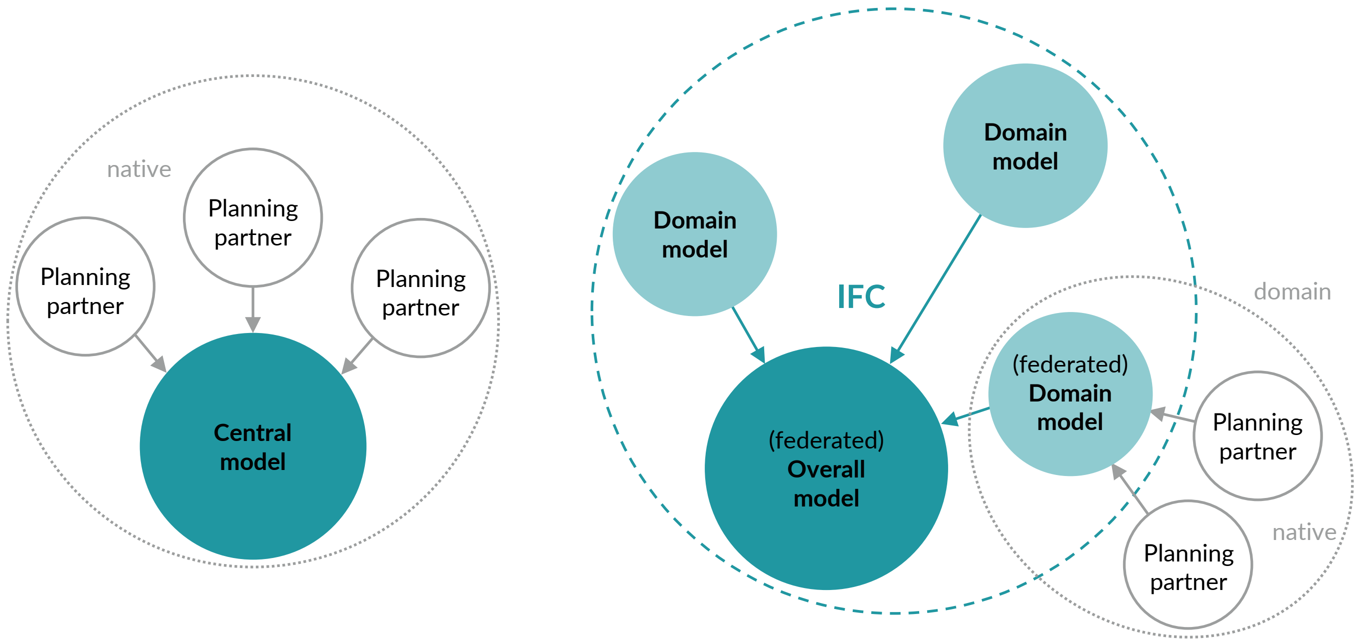
BIM must
- be readable for all alle,
- allow many to comment, and
- allow few to make changes.

Model-based collaboration not only concerns quality management in the overall model, but also (first) collaboration at the model level. According to **openBIM**, each domain planner who supplies model data creates it in his own software application (authoring software) as a domain model. Due to its data size, this can consist of sub-models, all created in the same (native) software application. The exchange of domain models takes place via the IFC interface. All domain models then flow together in the (federated) overall model.

Chapter 2 – Basic knowledge
2.4 Organisation



In contrast exists the system of a central model in which all domain planners work together using one software application (software family). This is referred to as **closedBIM**. Mixed forms are also possible. A domain planner can work together with his planning partners in closedBIM, but operate the (federated) overall model for coordination based on openBIM via IFC.



Quality management and the coordination of domain models in the overall model should always take place in a separate software application (checking software) which checks and evaluates the model data independently. Communication takes place digitally. Problem points are always transmitted in report form. This is done in PDF for documentation purposes and in BCF to allow the domain planners to see the problem directly in their software applications.

Like all project communication, the exchange of model data and reports (in PDF and BCF) takes place via the CDE provided for this purpose.

2.4.4 IDM methodology

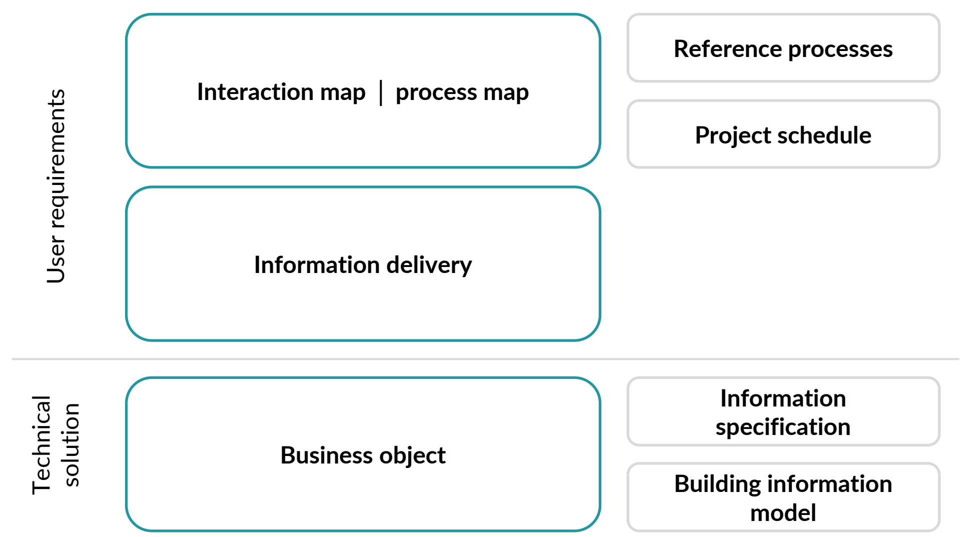
The exchange of models and model information between organisational units requires technically well-defined descriptions, terminology, and interfaces. This also includes the IDM and the MVD. The interaction between the IDM and the MVD is described in this section.

IDM – information delivery manual:
The IDM methodology supports the description of information requirements related to processes within the life cycle. IDMs have been developed by buildingSMART and certified as ISO standards (ISO 29481-1 and ISO 29481-2). These standards harmonise the creation and structuring of use cases. IDMs are created by using BPMN. buildingSMART provides templates for the creation of IDMs (see QR code). IDMs are used primarily by technical users and software developers. They use the following approach:

- What model information is required for a use case (use case definition, use case processes)?
- What additional inputs are needed?
- What does the originator provide, what is required by the recipient?
- Representation in a document and in a process map

An IDM, thus, defines the scope and type of an information request that is required or that must be supplied by dedicated BIM organisational units (roles) at a specific point in time (process) (exchange requirements). The description of an efficient exchange in the form of an IDM is very important because the relevant data transmitted must be communicated in a way that the receiving software can interpret the data correctly.

ISO 29481-2 defines IDM zones with respect to user requirements and technical solution:



In the interaction of the individual ISO and buildingSMART standards, the IDM is responsible for correctly describing the defined processes for an MVD (IFC Schema) using the bSDD, thus making them applicable.

MVD – model view definition:
The processes defined in an IDM are translated into concrete technical requirements in so-called MVDs. They represent a process-related subset of the entire IFC schema. MVDs describe the data exchange for a specific use or a specific workflow (application-specific data exchange requirements).

MVDs can be
- as wide as almost the entire schema (e.g., for archiving a project) or
- as specific as a few object types and associated data (e.g., for pricing a facade system).

They provide guidance for all IFC expressions (entities, relationships, attributes, and properties, property sets, set definitions, etc.).

An MVD can define an application-specific view for each project engineer and, thus, specify a subset or filtered view of the IFC (e.g., a limited element or data set). This defines »what« and »how« should be passed. Similar to IFC in XML, a MVD is machine-readable by mvdXML.

Documenting an MVD allows the exchange of these data to be repeated and provides consistency and predictability across a variety of projects and software platforms.

BIM rulebooks (EIR and BEP) refer to MVDs in the data formats to be used and in the transfer configuration specifications. The most common MVDs are:

IFC2x3 – **coordination view** (CV2.0): Spatial and physical components for design coordination between the fields of architecture, structural engineering (Structural analysis) and building services engineering (MEP, FM handover)

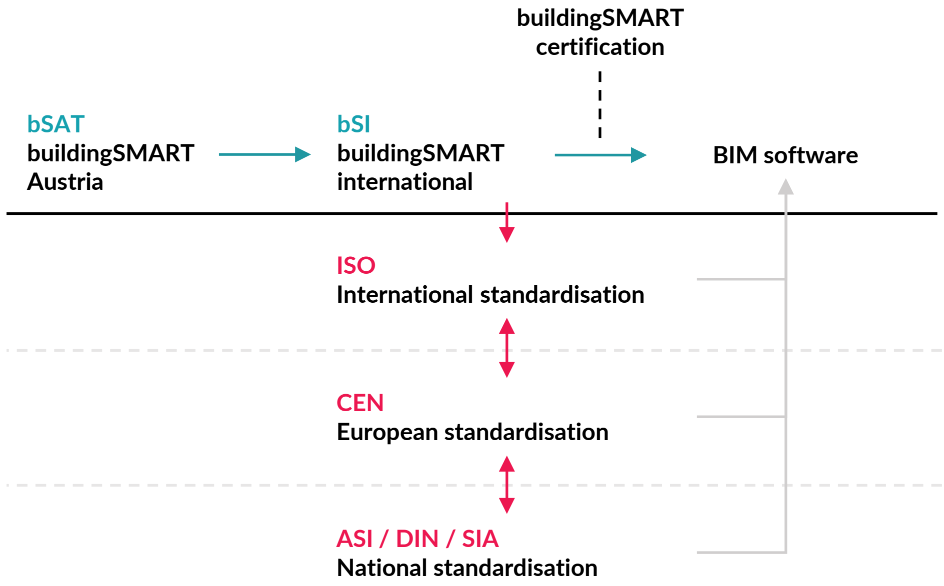
IFC4 – **reference view** (RV): Simplified geometric and relational representation of spatial and physical components to reference model information for design coordination between the architectural, structural, and building engineering domains.

IFC4 – **design transfer view** (DTV): Advanced geometric and relational representation of spatial and physical components to allow the transfer of model information from one tool to another. It is not a »back-and-forth« transfer, but a more accurate one-way transfer of data and responsibility.

The MVD, in interaction with the other ISO and buildingSMART standards, permits the application of the process specifications of an IDM using subsets of the IFC data structure to transport the required data using the bSDD.

2.5 Standardisation

Today there are over 6,500 different languages in the world. The exchange of information within the same language (closed) is easier than between different languages (open). In order to exchange information between the individual languages without major loss of information, many countries have agreed on a standard to be used – e.g., the language »English«. The openBIM method assumes a platform-neutral exchange of data. Thus, the implementation of the openBIM method requires clear and open standards so that information losses during information exchange are minimised. This section provides an overview of national, European, and international standardisation efforts.



2.5.1 International standardisation

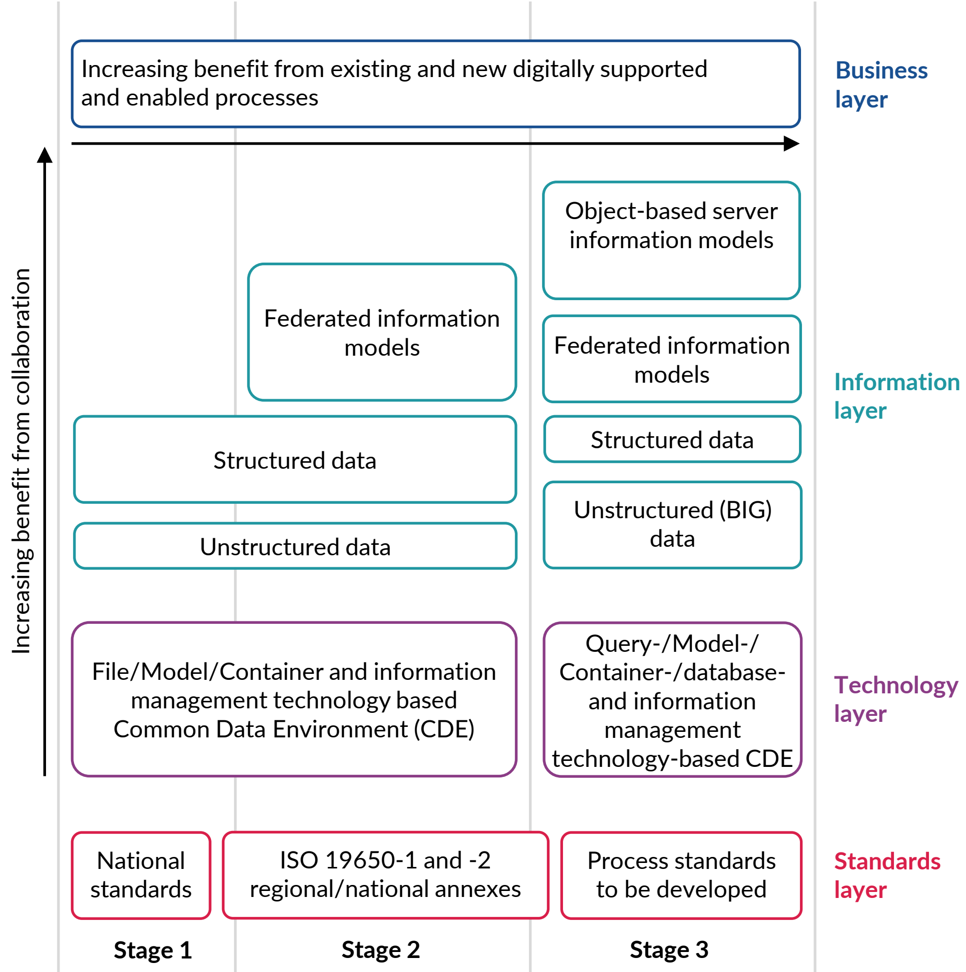
As an independent association, bSI develops its own standards. The best known are the IFC and the BCF. The object-oriented specification for IFC was first published in 1996 as IFC1.0. The current version, IFC4, was officially published in March 2013 as ISO 16739 and is being continuously developed. The current version is IFC4.3 TC1. This version includes new elements and location options for civil engineering and is currently undergoing ISO certification. ISO certification guarantees the sustainable usability of the model data. The certification of a software product applies not to the entire IFC data structure but to a specific Model View Definition (MVD).

In addition to the data structure, bSI is developing the international property server bSDD, which allows the international exchange of product information. The bSDD is based on ISO 12006-3, which defines the IFD. The IFD (International Framework for Dictionaries) is a framework for defining classification systems. Its basic principle is that all concepts can have a name and a description (regardless of language). However, only a unique identification code is utilised for identification and use. By attaching labels in multiple languages to the same concept, a multilingual dictionary is created.

The ISO 19650 standards provides process specifications defining BIM services and their implementation. All project participants should work together using the principles of ISO 19650 and improve information management. Open data formats should always be used. This standard refers to the workflow of information creation in a project as the information delivery cycle.

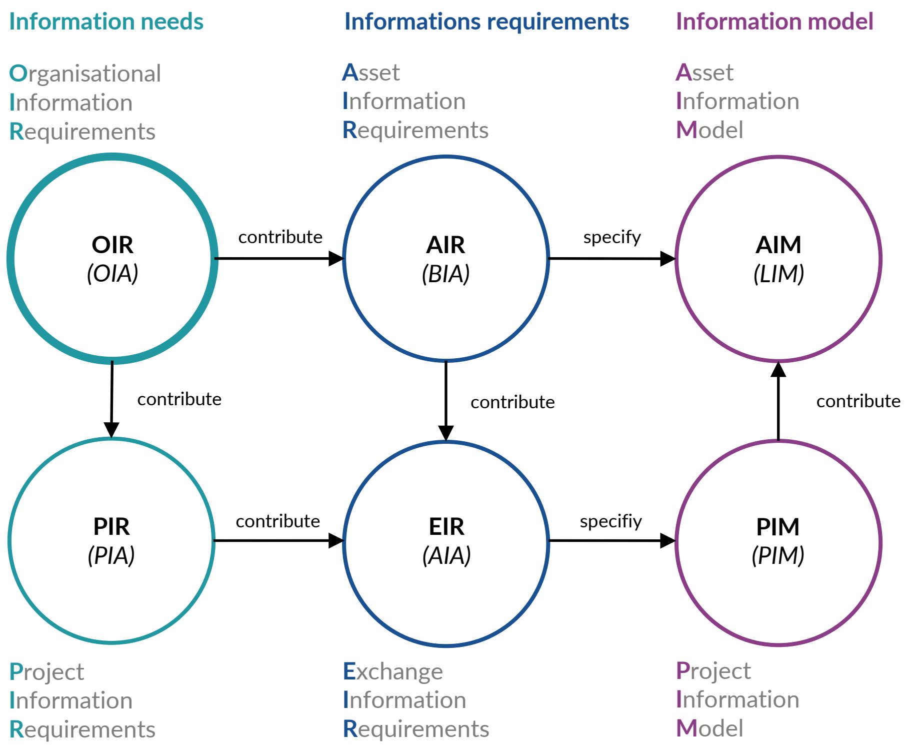
According to ISO 19650, the following BIM maturity levels (»BIM stages«) are distinguished with the corresponding development stages of information management:

- BIM stage 1: Combination of 2D CAD planning and 3D models as the standard for the planning of construction projects
- BIM stage 2: The consistent application of ISO 19650 (use of information management processes) and national and regional annexes, and the use of federated information models (compilation of multiple models)
- BIM stage 3: openBIM as the standard for the planning of construction projects



ISO 19650 has two time periods, each with a model. The Project Information Model (PIM) is used during the design and construction phase. The Asset Information Model (AIM) is used during the operational phase and should correspond to the current state of the structure. Both models contain both geometric and alphanumeric information. In addition, the project documentation may include information on the performance requirements during design, on the construction method and on the operation of the structure (e.g., maintenance costs, maintenance deadlines), etc. According to ISO 19650, these information models, thus, contain structured information containers (e.g., geometric models, schedules, databases) and unstructured information containers (e.g., documentation, video clips, sound recordings). The models have different requirements that influence each other:

- **OIR** organisational information requirements (to achieve the overarching strategic goals of the information requester),
- **PIR** project information requirements (required to respond to the overall strategic objectives in relation to a specific project),
- **AIR** asset information requirements (managerial, commercial, and technical aspects of the creation of information for the asset to be maintained = building), and
- **EIR** exchange information requirements (managerial, commercial, and technical aspects of project information preparation).



2.5.2 European standardisation

In 2015, the standardisation body CEN/TC 442 »Building Information Modeling (BIM)« was established at the European level. The committee develops a structured set of standards and reports. The aim is to establish the methodology for defining, describing, exchanging, monitoring, and recording asBuilt data (»asset data«), as well as for the safe handling of such data, semantics, and processes with the corresponding links to geodata and other external data.

This technical committee consists of four working groups:

- »Strategy and planning« (Secretariat Great Britain)
- »Exchange Information« (Secretariat Germany)
- »Information delivery specification« (Secretariat Austria)
- »Data dictionary« (Secretariat France)

Austria chairs the information delivery specification working group, which is dedicated to the central question: »Who delivers what, when, and in what quality, and who has to check it?«

2.5.3 National standardisation in Austria

The national standards for digital modelling are summarised in a separate digital standards group ÖNORM A 6241:

- ÖNORM A 6241-1:2015 »Digital building documentation - Part 1: CAD data structure and Building Information Modelling (BIM) - Level 2«
- ÖNORM A 6241-2:2015 »Digital building documentation - Part 2: Building Information Modelling (BIM) - Level 3-iBIM«

The ASI summarises the contents of their standards as follows:
ÖNORM A 6241-1 regulates the technical implementation of data exchange and data management of building information of structural engineering and related, space-forming constructions of civil engineering, which are required during the planning and in the course of the life cycle management of real estate, including the alphanumeric data contained in these building models. This ÖNORM also contains the most important terms, structures and presentation bases. It specifies the basic techniques for data transfer of two-dimensional CAD files and for Building Information Modelling (BIM).

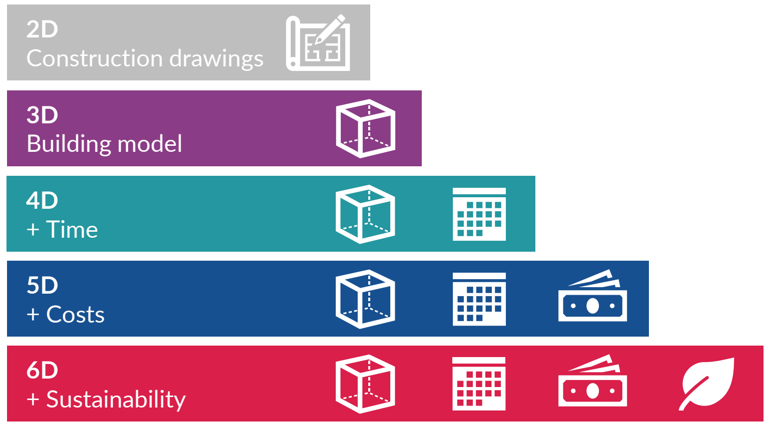
ÖNORM A 6241-2 regulates the technical implementation of a uniform, structured, a multi-dimensional data model for building structures and related spatial constructions in civil engineering, based on Building Information Modelling Level 3-iBIM. This ÖNORM also creates the basis for a comprehensive, uniform, product-neutral, systematised exchange of graphical data and the associated factual data on the basis of IFC and bSDD.

While ÖNORM A 6241-1 defines the general exchange of CAD files between project participants, ÖNORM A 6241-2 defines the basics for an openBIM data exchange based on IFC and bSDD. The standard is divided into the following sections Terminology, Project Model, Life Cycle of a Building (ÖNORM EN 16311), Dimensions, Level of Detail and IFC (incl. ASI Feature Server). The appendix also contains a rudimentary modelling guide, life cycle mapping to known other standards, levels of detail, project phases and a BIM workflow.

ÖNORM A 6241-2 describes the ASI Property Server. This is a kind of national property server. The definition of characteristics, including description, domain, type, project phase, etc., takes place in the ASI Property Server. These characteristics are linked to the international property server (bSDD) via the bSDD GUID.

The description of the billing of services is of great importance for the *AVA* process. The standard explicitly points out that invoicing can be done via models and not according to the standards of the service contract - if this is contractually agreed upon in advance. The term dimension is also introduced in ÖNORM A 6241-1. This is intended to describe the handling of virtual building model data in a project based on the factors of time, cost and sustainability:

- **3D – building model:** presence of geometric and alphanumeric information in a building model.
- **4D – time:** based on the model information, the construction schedule is determined/simulated.
- **5D – costs:** quantities and costs are determined semiautomatically in accordance with ÖNORM A 2063 with the help of standardised specifications. ÖNORM A 6241-1 points out that the quantity determination does not have to be carried out according to work contract standards. If an appropriate agreement between the client and the contractor exists, the quantity determination can be carried out based on the model.
- **6D – sustainability:** based on the model information, an assessment is made with regard to environmental, social, and economic issues.



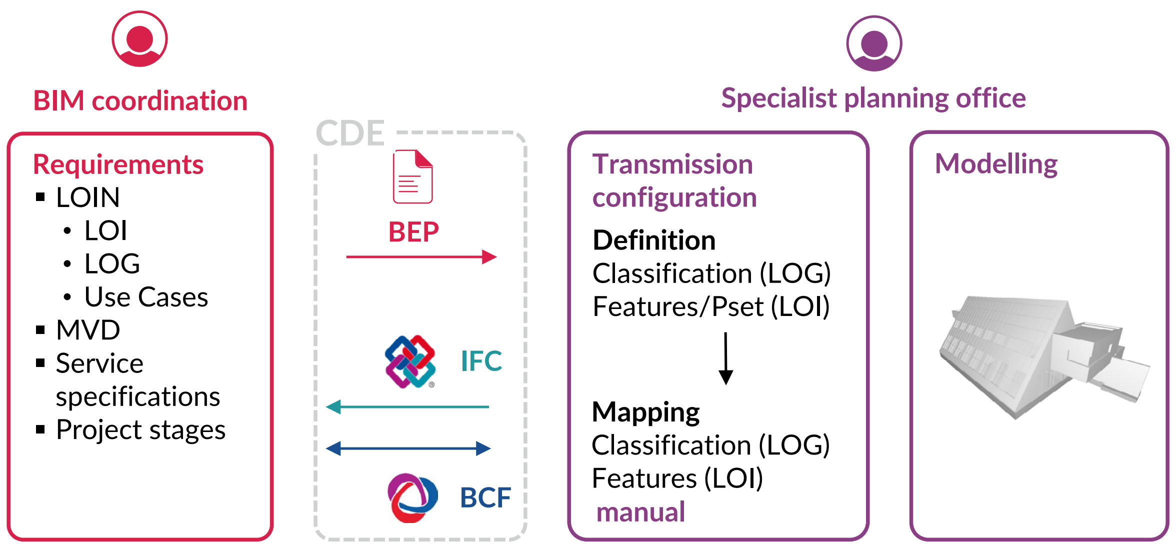
3 In-depth knowledge

This chapter provides a detailed insight into the various openBIM standards developed by buildingSMART. These new openBIM terms – especially the acronyms – are challenging, especially for newcomers. Understanding these terms is essential for the full use of openBIM. The contents of this chapter form the basis for the descriptions of openBIM project implementation in Chapter 4.

- Relevant for BIM newcomers, BIM practitioners, and BIM experts who would like to delve deeper into the technical details for extensive openBIM use,
- relevant for all those who want to take the certification exam for »Professional Certification - Practitioner«, and
- prior knowledge is assumed to be Chapter 1 and Chapter 2.

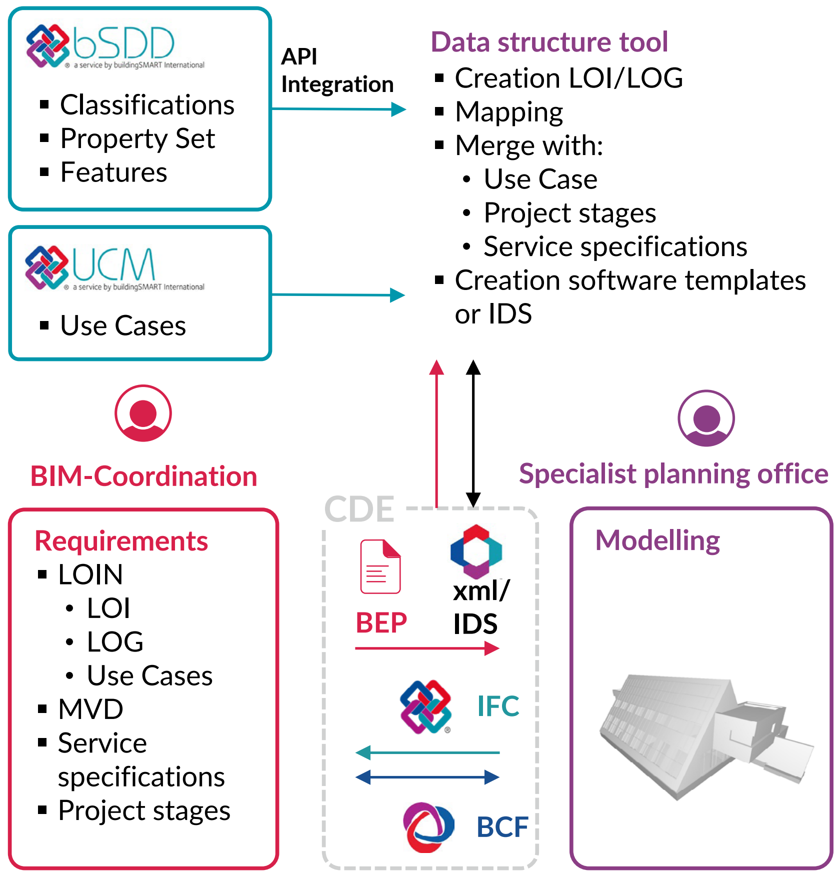
The following figures, therefore, put the terms into context. Unlike the overview illustration in Chapter 4, this illustration does not show the entire openBIM process within a project but only from the perspective of model creation. For more detailed information, please refer to the individual chapters.

The planning professional receives the model requirements (including LOIN, Section 3.6) via the BIM Execution Plan (BEP). They start to implement it in their native software. Before the actual professional modelling can begin, the first step is to create the new classifications (if allowed by the software policy) and the necessary features in the software. The second step is to map these to the IFC data schema (Section 3.2) for IFC export. This is followed by creating the domain model according to the Modelling Guide (Section 3.1.2). The office transfers the models using IFC and communicates via BCF (Section 3.4). All information exchange takes place via a Common Data Environment (Section 3.5).



The mapping described above has to be done manually by each project participant and project in the respective native software; this is not very efficient and prone to errors.

An improved method is to use a data structure tool (Section 2.3) to define centrally and map classifications and feature/property sets for multiple software and IFC data schemas or MVDs (Section 3.3). These are simultaneously linked to the service specifications (Section 2.4), project phases and use cases (Section 4) in a database. In addition, classifications and characteristics from the bSDD (Section 3.8) can be directly integrated by utilising an API. The results are software-specific templates or the IDS standard (Section 3.7), which can be imported directly into the software. Manual input into the modelling or checking software is no longer required. Who performs these activities in the data structure tool depends on the project and the organisation. The client may provide the data structure tool centrally and/or each actor uses its own data structure tool.



Some sources and recommended reading

Borrmann A., König M., Koch C., and Beetz J. (Eds.): »*Building Information Modeling: Technologische Grundlagen und industrielle Praxis*«. 2., revised edition, Springer Fachmedien, Wiesbaden, 2021, in German, ISBN: 978-3-658-33360 (see QR code).

Borrmann A., König M., Koch C., and Beetz J. (Eds.): »*Building Information Modeling: Technology Foundations and Industry Practice*”. Translated and Extended from the German Version, Springer International Publishing AG, Cham, 2018, ISBN: 978-3-319-92862-3 (see QR code).

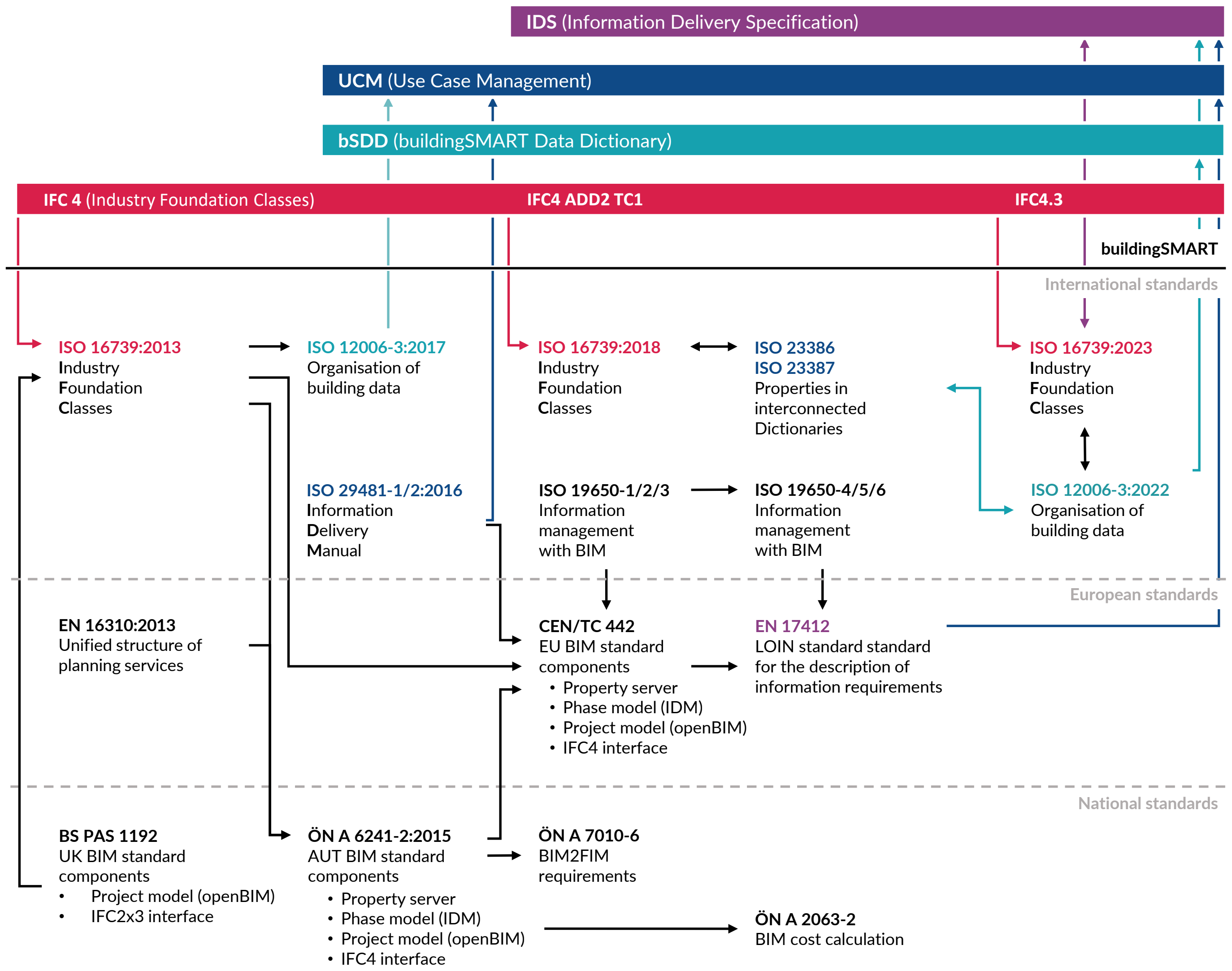
Hausknecht K. and Liebich T.: »*BIM-Kompendium – Building Information Modeling als neue Planungsmethode*«. Fraunhofer IRB Verlag, Stuttgart, 2016, in German. (2. edition expected in July 2023: https://www.baufachinformation.de/bim-kompendium/buecher/247752, see QR code).

Ratz L., Schranz Ch., and Urban H.: »*Industry Foundation Classes* und *deren Anwendung in openBIM-Projekten*«. Report, Centre Digital Building Process, TU Wien, 2020, in German.

Scherer R. J. and Schapke S.-E. (Eds.): »*Informationssysteme im Bauwesen 1: Modelle, Methoden und Prozesse*«. Berlin, Heidelberg, Springer-Verlag Berlin Heidelberg, 2014, in German, ISBN: 978-3-642-40882-3 (see QR code).

3.1 Standardisation

This section provides an overview of the primary openBIM standards and their national, European and international development. The standards mentioned in Chapter 2 are extended with additional standards and put into context (see next figure).



The figure shows the interdependencies of the different standards in chronological order. The basis for using openBIM is the vendor-neutral data structure IFC4, developed by bSI and certified in 2013 as ISO standard ISO 16739 »Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries«.

IFC provides the data structure for the exchange of geometric and non-geometric (alphanumeric) information. This alphanumeric information is primarily transported via the IfcPropertySet. The IfcPropertySet definitions are not anchored in the IFC schema; buildingSMART provides them as a separate specification. They are managed in the international property server bSDD, based on ISO 12006-3 »Building construction – Organization of information about construction works – Part 3: Framework for object-oriented information«. ISO 23387:2020 defines the interaction between IFC, bSDD, and digital product data (data templates) – the composition of which is defined by ISO 23386. The following definition applies:

- buildingSMART defined *property sets* begin with »Pset« in their designation. This also applies to *property sets* defined by national buildingSMART adapters.
- *Property Sets* ending with Common may only be defined by buildingSMART International (e.g., Pset_WallCommon).
- All other organisation- or project-specific *property sets* must start with a different prefix (e.g., ASI_feature list).

This makes it easier for project participants to see which features are project-specific.

Now that the information structure has been standardised, the question arises: In what form should the data be output by the software vendor? This is defined by the *Model View Definition* (MVD), which software vendors are certified to by bSI. The development of the MVD is done through the *Information Delivery Manual* (IDM). In an IDM, process representations define what information a model contains. This method is certified in ISO 29481-1/2 »Information Delivery Manual«. The model view definition defines the requirements for the IFC translator of the respective software. The next step after the standardisation of data structure and data exchange is the standardisation of *information management with BIM* in the ISO standards ISO 19650-1/2/3. ISO 23387 defines the interaction between IFC, bSDD, and digital product data (Data Templates), the composition of which is defined by ISO 23386.

The figure also shows the influence of IFC4 standardisation and the standardisation of a uniform classification of design services in EN 16310 on the national BIM standard – in Austria ÖNORM A 6241-2, which in turn has influenced the European working group for BIM »CEN/TC 442«, which is striving to develop a harmonised European openBIM standard. With EN 17412, CEN/TC 442 has already published the single LOIN definition. In contrast to various national BIM standards, the publications of CEN/TC 442 are of much greater importance to the software industry, as they represent the requirements of a much larger market.

3.1.1 International standards

ISO 16739:2013
As an independent association, bSI develops its own standards. The best known is IFC, which enables the exchange of model information across software products. The current version, IFC4, was officially published as ISO 16739 in March 2013 and is under continuous development.

EN 16310:2013
At the European level, EN 16310 was published in 2013. This standard deals with the unified classification of engineering services. This document defines terms related to engineering services. A harmonised glossary of key construction terms at the European level is intended to promote free competition in the EU. At the same time, it is intended to reduce problems in cross-border cooperation resulting from different interpretations of relevant terms in different European countries. The focus is on the entire engineering services sector (construction of buildings, infrastructure, and industrial facilities). The life cycle of construction works is divided into several sections, each of which is subdivided into sub-sections:

		Stages	Sub Stages
Before use stage	Product stage	0. Initiative	0.1 Market study 0.2 Business case
Before use stage	Product stage	1. Initiation	1.1 Project initiation 1.2 Feasibility study 1.3 Project definition
Before use stage	Product stage	2. Design	2.1 Conceptual design 2.2 Preliminary design and developed design (B&I) 2.3 Technical design or FEED 2.4 Detailed engineering
Before use stage	Product stage	3. Procurement (IF)	3.1 Procurement 3.2 Construction contracting
Before use stage	Construction stage	4. Construction	4.1 Pre-construction 4.2 Construction 4.3 Commissioning 4.4 Hand over 4.5 Regulatory approval
Use stage		5. Use	5.1 Operation 5.2 Maintenance
End-of-life stage		6. End-of-life	6.1 Revamping 6.2 Dismantling

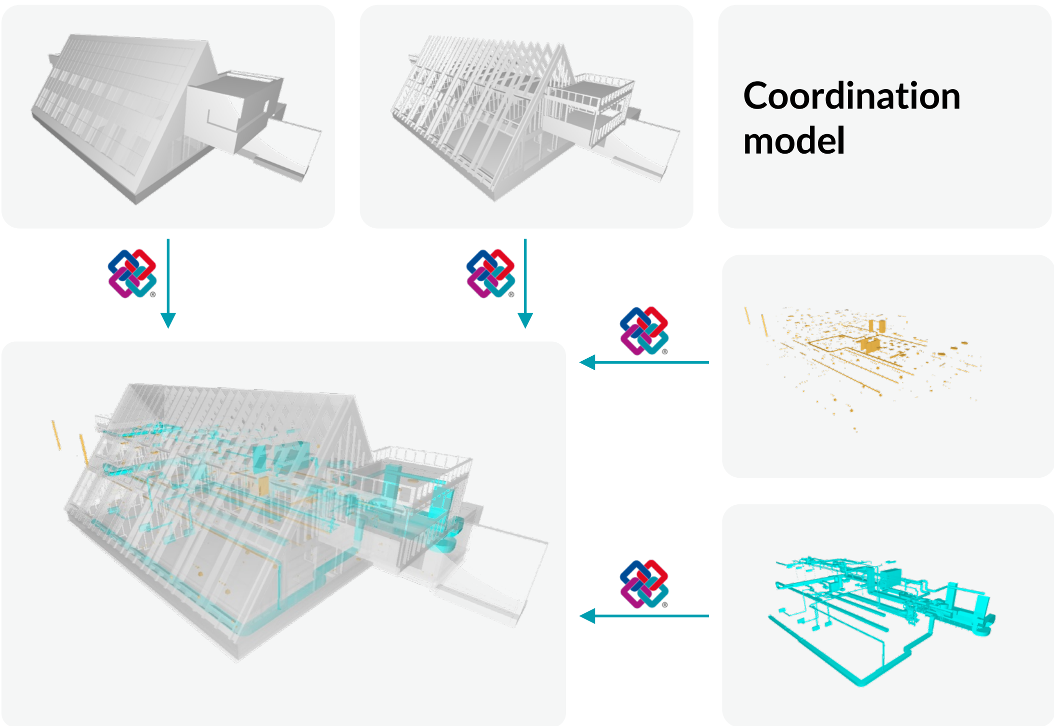
from EN 16310:2013

This outline and the IFC data structure influenced the preparation of the Austrian standard ÖNORM A 6241-2 »Digital structure documentation – Part 2: Building information modeling (BIM) – Level 3-iBIM«.

ISO 12006-3:2022 (bSDD Propertyserver)
The IFC data structure is complemented by bSDD. It is a web-based service for creating and consolidating individual data structure supplements (ontologies) based on ISO 12006-3, which defines the IFD (International Framework for Dictionaries). The IFD is a framework for the definition of classification systems. The basic principle is that all concepts can have a name and a description (regardless of language). However, only a unique identification code is relevant for identification and use. A multilingual dictionary is created by attaching labels in several languages to the same concept.

ISO 29481-1/2
The IDM methodology is certified to ISO 29481-1/2. It supports the description of information requirements related to processes within the life cycle. MVDs are developed based on this IDM.

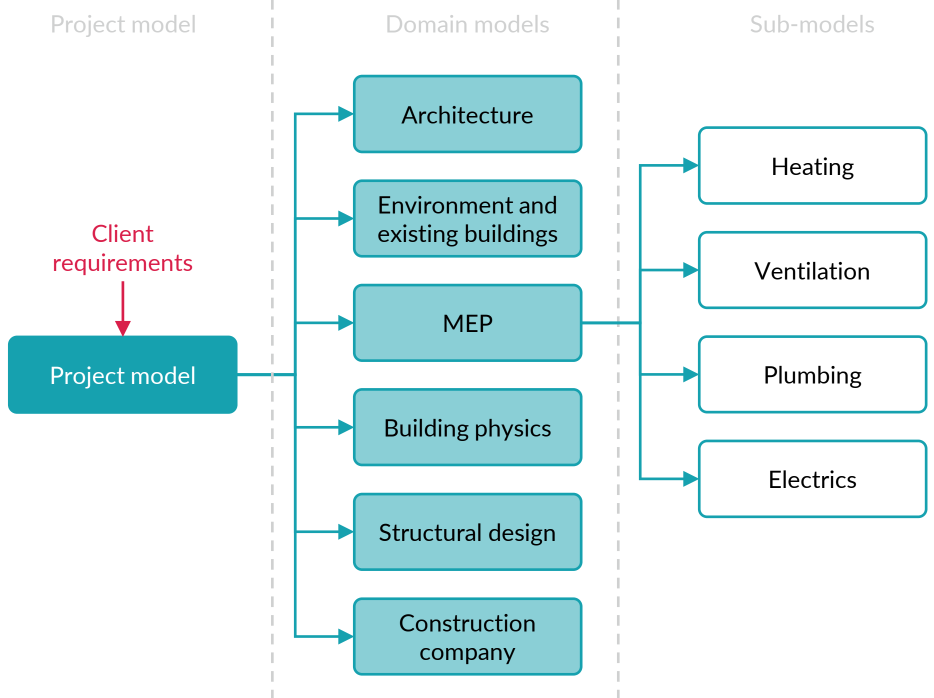
ISO 19650-1/2/3
ISO 19650-1/2/3 contains process specifications that define BIM services and their implementation. Part 1 contains the description of terms, concepts, and principles. Part 2 describes information management in the design, construction, and commissioning phases. Part 3 covers the operational phase of assets (buildings).



3.1.2 National standards in Austria

ÖNORM A 6241-2
ÖNORM A 6241-2 is part of the separate digital standardisation group A 6241. While ÖNORM A 6241-1 focuses on the general exchange of CAD data (e.g., clear naming of layouts and blocks), part 2 deals with the openBIM methodology. ÖNORM A 6241-2 regulates the technical implementation of a uniform, structured, multidimensional data model for building structures based on *Building Information Modelling Level 3-iBIM*. This ÖNORM creates the basis for a comprehensive, uniform, product-neutral, systematised exchange of graphical data, and associated factual data based on IFC and bSDD.

ÖNORM A 6241-2 was published before ISO 19650-1. As a result, the terms between the standards are different. Therefore, the terms from ISO 19650-1 are given in brackets after the respective term from ÖNORM A 6241-2 when it is mentioned for the first time. Section 7 »Levels of detail« of ÖNORM A 6241-2 is currently under revision. The first section of the standard defines general terms. A description of the project model follows this. A project model is created based on the client's requirements (EIR). This (federated) project model consists of domain models, which can be divided into sub-models:



The level of detail depends on the life cycle phase of the building. These life stages have been defined in accordance with ÖNORM EN 16310 and are compared in »Annex B Allocation of life stages«. Annex C describes the exact level of detail according to the life cycle of a building.

The final section of the standard describes the IFC data schema (then IFC2x3) as a software vendor independent standard for information exchange in the building industry. The appendix also contains a rudimentary modelling guide.

ÖNORM A 7010-6
ÖN A 7010-6 was published in 2019 and describes the information needs of clients and operators for BIM projects. This description is provided generically in tabular form for typical site elements (such as plots, buildings, floors) and operationally relevant equipment elements (such as doors, windows, relevant components of ventilation systems/fire alarm systems). All relevant details required for maintenance, care, inspection, repair, or replacement are defined. The subsequent description of the specific implementation based on the IFC specification will take place in the planned ÖN A 6241-3.

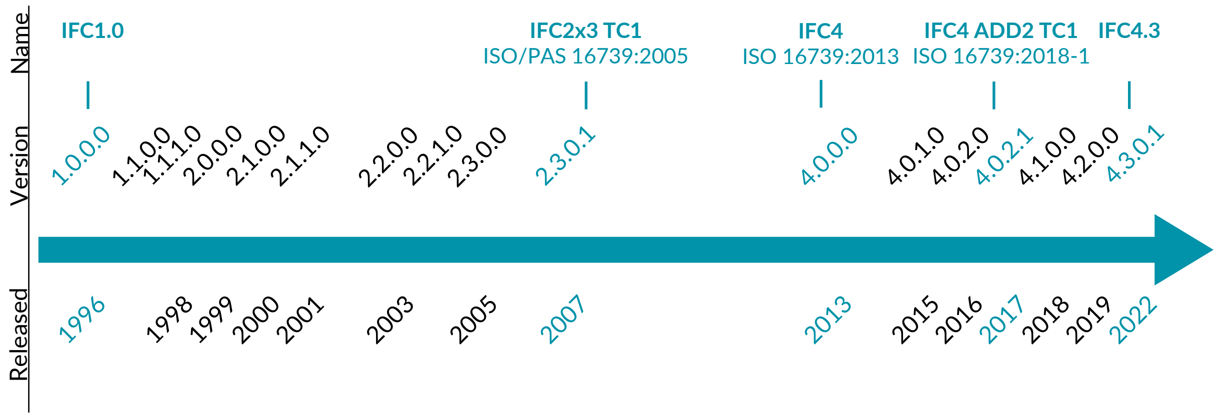
3.2 IFC – industry foundation classes

This section describes in detail the structure of the IFC data structure – an essential basis for the exchange of digital building information. IFC is both a data structure and a data format for sharing building data. After the general basics, key terms are defined. This is followed by an explanation of the data schema architecture and the basic modelling concepts, namely conceptual layers, inheritance hierarchies, domains, element classes, relationship mappings, attributes, properties and object types.

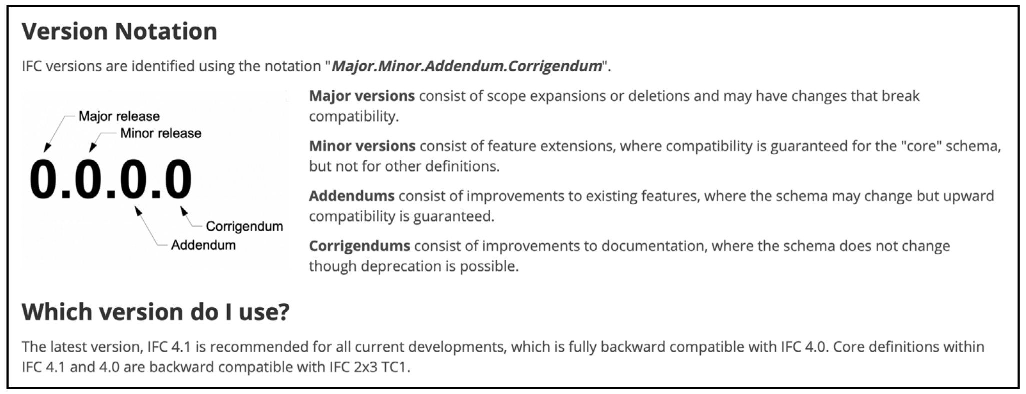
3.2.1 General principles

This subsection provides insight into the origins and development of IFC, its underlying data modeling language and common file formats.

In the 1980s, in an effort to create uniform interfaces between heterogeneous CAD systems, the standardisation framework »*STEP – Standard for the Exchange of Product Model Data*« was defined in the ISO 10303 standard. In the mid-1990s, a group of engineering firms, construction companies, and software manufacturers, with Autodesk, Bentley, and Nemetschek playing a major role, joined forces to form the International Alliance for Interoperability (IAI), which was renamed »buildingSMART« about ten years later. Their ambition was to make the standardisation of the building industry more efficient. In 1996, they published the first version of the Industry Foundation Classes: IFC1.0. Software vendors implemented the standards in their products, which buildingSMART published free of charge and vendor-neutral, independent of ISO certifications. In 2007, the version IFC2x3 TC1 was released, which was the first version to receive ISO certification. The current, fourth version (IFC4) was released in 2013 and certified as ISO standard ISO 16739:2013 »Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries«. By 2018, IFC4 had been revised in several steps to IFC4 ADD2 TC1 (published as ISO 16739:2018). In particular, the requirements of the software industry from software certification processes for the MVD Reference View were incorporated into this revision. The current version of the IFC in 2023 is IFC4.3. This will soon be published as ISO 16739:2023. Versions of IFC published to date can be found in the »IFC Specifications Database« of buildingSMART and are shown in the next figure.



Over the course of the time period since the release of IFC1.0, buildingSMART used different official notations or version identifiers, e.g., IFC2.0, IFC2x3, or IFC4. However, at the buildingSMART Summit 2019 in Düsseldorf, buildingSMART introduced a new (permanently stable) ***version notation*** (designation logic). This notation is now in force and can be found on the buildingSMART website (see QR code):


Version Notation

IFC versions are identified using the notation "***Major.Minor.Addendum.Corrigendum***".

Major versions consist of scope expansions or deletions and may have changes that break compatibility.

Minor versions consist of feature extensions, where compatibility is guaranteed for the "core" schema, but not for other definitions.

Addendums consist of improvements to existing features, where the schema may change but upward compatibility is guaranteed.

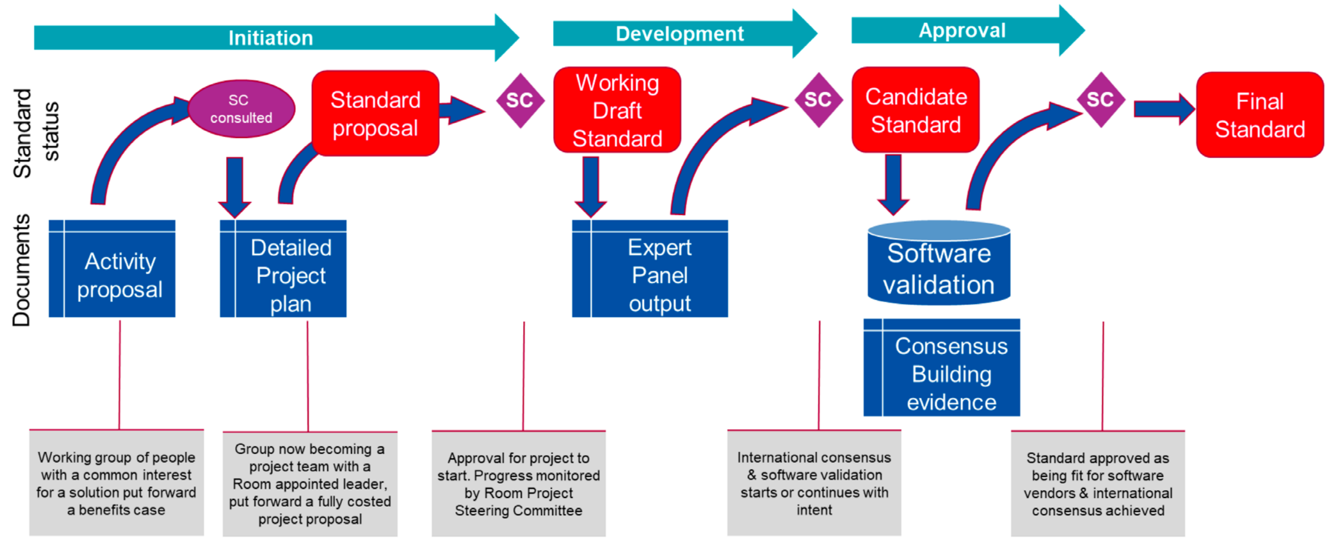
Corrigendums consist of improvements to documentation, where the schema does not change though deprecation is possible.

Which version do I use?

The latest version, IFC 4.1 is recommended for all current developments, which is fully backward compatible with IFC 4.0. Core definitions within IFC 4.1 and 4.0 are backward compatible with IFC 2x3 TC1.

The notations of the versions are composed of four digits that stand for »***Major.Minor.Addendum.Corrigendum***«. If the first digit changes, there are significant changes (***Major***) that can affect the compatibility with former versions. A new major version can generally be expected every ten years. This includes a fundamental leap in development, e.g., with IFC5 (5.0.0.0) the complete revision of the MVD concept. In the case of minor changes (***Minor***), the compatibility of the »core« schema with former versions is guaranteed. Minor versions are therefore intermediate steps for the integration of new functionalities, e.g., with IFC4.1 (4.1.0.0) the inclusion of the IFC alignment or with IFC4.3 (4.3.0.1) the inclusion of the data structure components for transport infrastructure facilities (road and rail). An ***addendum*** can contain selective improvements for existing functions, e.g., with IFC4 Add2 (4.0.2.0) the introduction of NURBS surfaces for BREP transmission. Upward compatibility is guaranteed. A ***corrigendum*** does not change the schema, but functions can be made invalid (*deprecated*). Corrigendums are also adjustments/corrections to the documentation, e.g., with the improvement of the EXPRESS schema with IFC2x3 TC1 (2.3.0.1).

New developments of a *minor version* are released as *Release Candidates* (e.g., 4.3.0.1) in a standardised, multi-stage procedure (*Project Delivery Governance*, see QR code), which is specified and monitored by the Operations Director of buildingSMART International (see figure below).



The version currently most widely used in practice is IFC2x3, which is increasingly being replaced by IFC4 as the availability of IFC4-certified software increases. This book refers to the latest IFC specification, IFC4.3 (see QR code for documentation).

IFC is the essential foundation for the realisation of openBIM, in particular for almost all initiatives in the public sector that aim to make BIM or digitisation mandatory in public construction projects. The standard provides definitions for data that is relevant to buildings and associated technical equipment throughout their lifecycle. In addition, the scope of data definitions is currently being extended to transport infrastructure (road and rail) with IFC4.3.

IFC specifies a data schema and a file format. The ***scope*** of IFC4.3 describes the data modelling language underlying the data schema and the applicable file formats. The IFC data schema is based on the EXPRESS data modelling language, which is governed by Part 11 of the STEP standard (ISO 10303-11). In addition to the textual notation, the standard defines a graphical notation for mapping the data, EXPRESS-G. In the documentation of the IFC4.3 data schema, illustrations using EXPRESS-G can be found. Instead of EXPRESS, the data modelling language XML defined in ISO 10303-28 can also be used, where the XML notation is derived from the EXPRESS notation. In a lecture, Prof. Rasso Steinmann describes this EXPRESS schema as a *cake form* that does not yet describe concrete instances of the data model. Various file formats are offered for the exchange of concrete model data. buildingSMART recommends the SPF (*STEP Physical File*) format, which is defined in ISO 10303-21. The file extension is ».ifc«. This is also available in a compressed version that compresses an IFC file using a ZIP container. In this case, the file extension is ».ifczip«. In addition, there is also the usable XML file format with the extension ».ifcXML« (see QR code), which transports model data in a less compact form than ».ifc« and has hardly been used in practice to date.

An IFC file can be opened by any text editor. Each IFC file consists of a HEADER section and a DATA section. The HEADER section contains information about the model view definition, the file name and path, the author, the software used, and the IFC schema used for the export. A HEADER section can look as follows:

```
ISO-10303-21;
HEADER;FILE_DESCRIPTION(('no view'),'2;1');
FILE_NAME(
'C:\\Users\\Linda\\Allplan Testprojekt\\TestprojektW\
X2\00E4\X0\nde.ifc',
'2020-02-16T11:20:17',('Linda'),('Nemetschek AG',
'Konrad-Zuse-Platz 1, 81829 Munich / Germany'),
'EDMsix Version 2.0100.09 Sep 7 2016',
'Allplan 2019.1 24.06.2019 - 16:10:06','');
FILE_SCHEMA(('IFC4'));
ENDSEC;
```

In this example, a building model was created with Allplan 2019-1 and exported using the integrated IFC interface, where the IFC4 schema was selected. As a second option, export with the IFC2x3 schema can be chosen, which is currently more widespread and for which Allplan has been certified.

The DATA section contains information about the project. Each ***instance*** (see Section 3.2.2) is given a file-internal identifier in the STEP physical file format, which consists of a number preceded by a hashtag (#). A section of a DATA section can look as follows:

```
#347= IFCCARTESIANPOINT((0.,0.));
#349= IFCCARTESIANPOINT((10000.,0.));
#352= IFCRELASSOCIATESMATERIAL('3CStp9Q6j9PfrLpnWPTT4W',#11,$,$,(#386),#383);
#353= IFCMATERIALLAYERSET((#355,#369),$,$);
#355= IFCMATERIALLAYER(#356,100.,$,$,$,$,$);
#356= IFCMATERIAL('Grafische hart',$,$);
#357= IFCPRESENTATIONSTYLEASSIGNMENT((#359,#167));
#359= IFCCURVESTYLE($,#117,$,#118,$);
#360= IFCSTYLEDITEM($,(#357),$);
#362= IFCSTYLEDREPRESENTATION(#61,$,$,(#360));
#364= IFCMATERIALDEFINITIONREPRESENTATION($,$,(#362),#356);
#369= IFCMATERIALLAYER(#370,300.,$,$,$,$,$);
#370= IFCMATERIAL('C25/30',$,$);
#371= IFCPRESENTATIONSTYLEASSIGNMENT((#373,#119));
#373= IFCCURVESTYLE($,#117,$,#118,$);
#374= IFCSTYLEDITEM($,(#371),$);
#376= IFCSTYLEDREPRESENTATION(#61,$,$,(#374));
#378= IFCMATERIALDEFINITIONREPRESENTATION($,$,(#376),#370);
#383= IFCMATERIALLAYERSETUSAGE(#353,.AXIS2.,.POSITIVE.,-0.,$);
```

```
#386= IFCWALLSTANDARDCASE('3QrME8v0LDvhhz5vzIpgYG',#11,' ',$,$,#299,#300,$,$);
#390= IFCPROPERTYSINGLEVALUE('K_WAND_TYP',$,IFCTEXT('WD\\BETON'),$);
```

3.2.2 Definitions

The following definitions of terms refer to the definitions of the IFC4.2 specification (see QR code) as well as definitions and translations from the bSDD.

Class, also referred to as entity, element class, entity type:
An entity, as defined by the IFC, is a class of information defined by common attributes and constraints as specified in ISO 10303-11. Attributes and relationships to other entities / entity types are defined for each entity. The object-oriented concept of inheritance is implemented. This means that attributes and relationships are passed on to subtypes. A distinction is also made between abstract and non-abstract entities. For example, an abstract entity is IfcFlowTerminal with the associated non-abstract entities IfcAirTerminal, IfcSanitaryTerminal and IfcWasteTerminal etc. This functionality is necessary, among other things, to ensure backward compatibility with earlier versions of IFC, which did not offer the detailed declaration options of today's versions of IFC.

Object and instance, also referred to as specimen, entity instance:
An object is a tangible or imaginable object that can exist physically (like a wall) or be purely conceptual (like a load, a room, or a task). In the object-oriented modeling approach used in IFC, an object is also referred to as an instance or copy of a class. The class represents a kind of template for the creation or instantiation of objects. It thus describes the structure and behavior of similar objects.

Object type:
Similar to the class, an object type is also a kind of template that combines common characteristics of several instances. However, certain basic parameters that remain the same for repeating components are defined before the actual instantiation. A detailed explanation can be found in Section 3.2.10.

Attribute, also referred to as parameter:
According to the IFC definition, an attribute is a unit of information within a class. There are three *types* of attributes: *direct*, *inverse*, and *derived* attributes. Attributes are a way of statically defining properties for classes in IFC. This is explained in more detail in Section 3.2.9. Dynamic properties provide another option. Attributes are not set up by the modeler but created automatically by the software, such as the quantities described below.

Quantity:
A quantity is a key parameter derived from the physical properties of an object, such as a room or a building component. Possible units of measurement for quantities are length, area, volume, weight, number, and time.

Quantity Set:
A quantity set is a specific container in which quantities are assigned to an entity. Its name depends on the associated entity, e.g., in the case of IfcActuator: Qto_ActuatorBaseQuantities.

Property:
A property is a unit of information that is dynamically defined as an entity instance of the IfcProperty class. It can be used to describe the nature of an object.

Property set:
The IfcPropertySet is a container that carries properties in a property tree structure. Some predefined property sets are included in the bSDD. In addition, any user-defined property set can be captured. A more detailed explanation can be found in Section 3.2.9.

In addition to the already existing specifications, the IFC data structure allows the definition of individual supplements. These can be defined project-specifically in a local framework (e.g., with a data structure tool) and are communicated to the project team (using the EIR) or consolidated (using the BEP) via BIM rules. The following ***naming convention*** exists for such additions (see QR code):

- Types, classes, rules, and functions have the prefix »Ifc«.
- Attributes of classes have no prefix.
- *Property sets* that are part of the IFC standard have the prefix »Pset_«.
- *Quantity sets* that are part of the IFC standard have the prefix »Qto_«.

The names of these data types are composed of English words concatenated without any space between them (***CamelCase***). The first letters of the words are capitalised and there is no underscore between the words. An example of this notation is *OwnerHistory*.

3.2.3 Conceptual layers

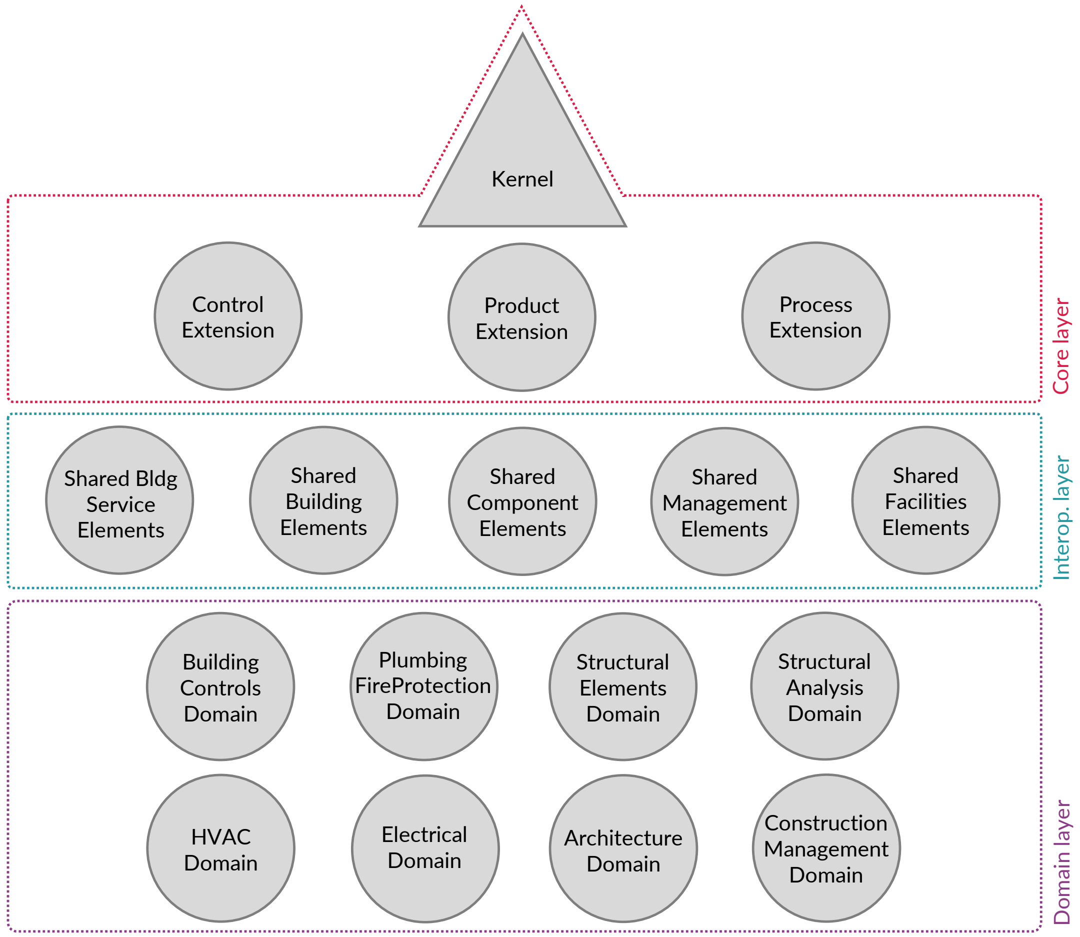
The IFC data schema architecture defines four ***conceptual layers***, where each schema is assigned to exactly one of these layers (see previous QR code for the naming convention). The figure on the following page shows the first three layers. The four conceptual layers are:

1. ***Core layer:***

   This first layer contains the most basic classes of the data model. They can be referenced, i.e., reused and concretised, by classes of the *interoperability layer* and the domain layer. Basic structures, fundamental relationships, and general concepts are defined here. All classes of the three layers shown in the following figure have a GUID (*globally unique identifier*) and can also have an *owner* and a *history* (see Section 3.2.4).
   The *core layer* consists of the *kernel* (core) and the three *core extension subschemas* (extension schemas) which are used to group basic *entities*:

- The ***kernel*** contains the most abstract class IfcRoot, which is the superclass of all classes of the first three layers. Direct subclasses of IfcRoot are IfcObjectDefinition, IfcPropertyDefinition, and IfcRelationship. IfcObjectDefinition is a superclass for classes that allow the instantiation and typing of physically tangible or existing objects, persons, and

processes. These include, e.g., the classes IfcContext (with the subclasses IfcProject and IfcProjectLibrary), IfcElement, IfcSpatialElement (with subclasses IfcSite, IfcBuilding, IfcSpace, etc.), IfcElementType, IfcStructuralActivity, IfcStructuralItem, IfcActor, IfcProcess, and IfcResource.
IfcPropertyDefinition contains classes for grouping properties and providing templates for properties. Examples of the classes are IfcPropertySet, IfcQuantitySet, IfcPropertyTemplateDefinition, and IfcPreDefinedPropertySet. The concept of properties is described in detail in Section 3.2.9.
IfcRelationship is the superclass for all relationship objects that are used to link classes. It describes relationships between objects, between properties, and between objects and properties. This is explained in Section 3.2.8, where examples are also given.



- The control extension declares basic classes for control objects (IfcControl and IfcPerformanceHistory, etc.) and relationship classes for assigning these classes to objects (such as IfcRelAssignsToControl). IfcControl includes classes that control or restrict the use of products, processes, and resources through rules, requests, or statements.
- The product extension is for classes of physical objects that usually have a shape and location within the project. These are, e.g., elements for creating a spatial project structure and construction elements. The product information is provided as subclasses of IfcProduct for instances and as subclasses of IfcTypeProject for object types.

- The process extension expands the concept of the IfcProcess described in the IfcKernel. It contains classes for the logical mapping of processes and for task and work scheduling. The goal is to map information that is commonly used in process mapping and scheduling applications. Examples of classes in this schema are IfcTask, IfcWorkPlan, and IfcEvent. IfcTask is used for identifiable units of work, e.g., in the design or construction processes. An IfcWorkPlan is a work plan that can reference other work plans of the IfcWorkSchedule class, tasks of the IfcTask class, and required resources. IfcEvent is used to record actions that trigger responses or reactions, e.g., to identify a point in time at which information is issued.

2. *Interoperability layer:*

This layer contains classes that can be used in different disciplines and exchanged between them. They can be referenced and specialised by all classes below them in the hierarchy, i.e., those in the domain layer.

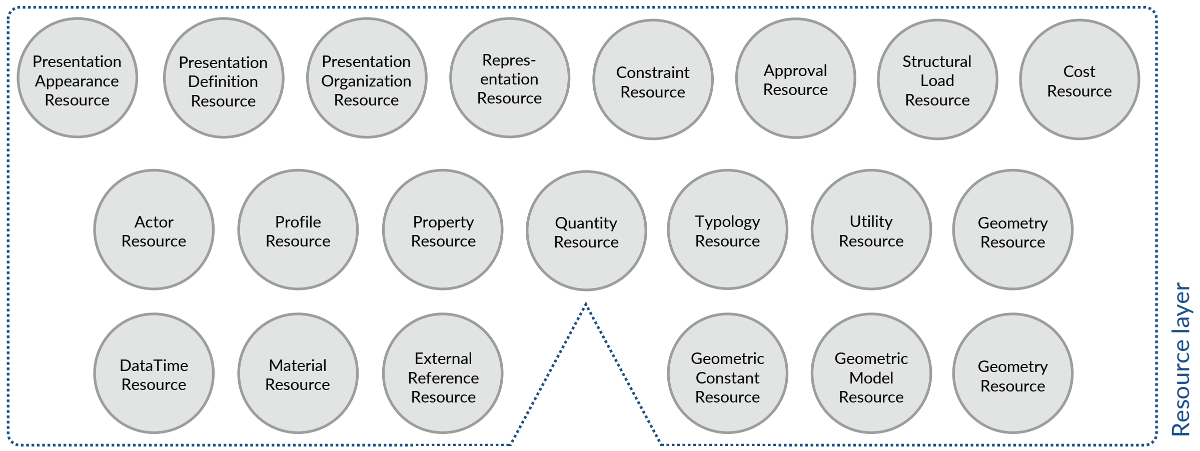
- The most important component of this layer is the ***shared building elements*** schema, which contains important building element classes such as IfcWall and IfcSlab. These and other subclasses of IfcElement are used to represent the most significant functional part of a building. The classes of the interoperability layer are derived from classes of the ***core layer***, as is the case for the classes of the *Shared Building Elements* schema of IfcElement.
- The ***shared building service elements*** schema defines classes for modeling flow and distribution systems and lists of features for describing building services, such as flow properties, electrical properties, and room thermal properties.
- The ***shared component elements*** schema includes concepts for various small parts such as accessories and fasteners. One notable class is IfcElementComponent, which provides a representation for smaller elements that are not relevant from the perspective of the overall building structure. An example are connecting elements.
- The ***shared management elements*** schema defines concepts for the management of the project. The classes of the schema are subclasses of IfcControl. The goal is to provide information classes that support the control of project scope, cost, and time.
- The ***shared facilities elements*** schema defines base classes for facility management (FM), including classes for mapping furniture and other items.

3. *Domain layer:*

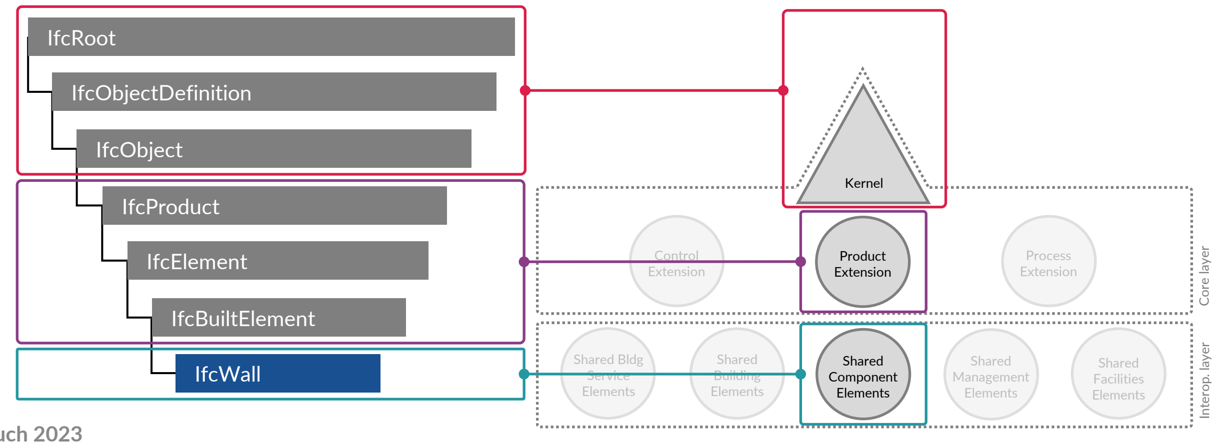
This layer organises element classes by disciplines of construction. It contains schemas that contain specialisations of products, processes, or resources that are specific to one of eight disciplines (domains). An example of this is the *Architecture Domain* schema, which contains IfcDoor and IfcWindow, among others. The classes in this layer cannot be referenced or further specialised by any other layer.

4. ***Resource layer:***

This layer (see figure), which must be considered separately, contains all schemas that include supporting resource definitions. These are not subclasses of IfcRoot (hence, they are called *non-rooted classes*), so they have ***no GUID*** and cannot exist as standalone elements. They must therefore be referenced by at least one class of one of the other three layers. Examples of these classes are IfcMaterial, IfcCartesianPoint, IfcFacetedBrep, IfcPerson, IfcPropertySingleValue, IfcObjective and IfcRegularTimeSeries. Some essential schemas of the layer are IfcMaterialResource, IfcGeometricModelResource, and IfcDateTimeResource.



The conceptual layers of the data schema architecture are described based on a use case in the following figure. The IfcWall element class (see QR code) is part of the *Shared Building Elements* schema located in the interoperability layer. It is a subclass of IfcBuildingElement of the *Product Extension* schema of the core layer. IfcBuildingElement in turn is a subclass of IfcElement, which is a subclass of IfcProduct. Conversely, it can also be said that the superclass of IfcProduct is the class IfcObject, which belongs to the *kernel*, which is also in the core layer.



The superclass of IfcObject is IfcObjectDefinition, whose superclass is the most abstract of all classes, IfcRoot, which is the origin of all classes that rise from the *kernel*.

3.2.4 Inheritance hierarchy

In programming, inheritance means that a subclass can receive (inherit) the properties of one or more superclasses. The subclasses possess additional information and represent specialisations while the superclasses are generalisations.

Attribute inheritance

In IFC, both relationships and attributes can be inherited. The implementation of relationships in IFC is discussed in Section 3.2.8. In the following paragraphs, the inheritance of attributes is explained by using the class IfcWall as an example. This class gets its available attributes from classes IfcRoot, IfcObjectDefinition, IfcObject, IfcProduct, IfcElement, IfcBuildingElement, and from IfcWall itself.

The following figure shows a section of the *attribute inheritance* table for IfcWall (see the QR code for IfcWall). The section shows the attributes of IfcRoot, which are inherited by all classes that originate in the *kernel*, i.e., all classes except those of the *resource layer*. IfcRoot thus forms the root of the inheritance tree of most classes. It provides the IfcGloballyUniqueId (*GUID*) attribute, which is necessary to uniquely identify objects. The *GUID*, which is automatically generated, is a 128-bit number that is compressed to a 22-digit number in order to reduce storage space for data exchange. The *Owner History* is another attribute of IfcRoot, which provides information about the current and past ownership and about the time of the last modification. »*Name*« and »*Description*« attributes allow a name and comment to be added (optional).

#	Attribute	Type	Description
IfcRoot (4)			
1	GlobalId	IfcGloballyUniqueId	Assignment of a globally unique identifier within the entire software world.
2	OwnerHistory	OPTIONAL IfcOwnerHistory	Assignment of the information about the current ownership of that object, including owning actor, application, local identification and information captured about the recent changes of the object, NOTE only the last modification in stored - either as addition, deletion or modification. IFC4-CHANGE The attribute has been changed to be OPTIONAL.
3	Name	OPTIONAL IfcLabel	Optional name for use by the participating software systems or users. For some subtypes of IfcRoot the insertion of the Name attribute may be required. This would be enforced by a where rule.

3.2.5 Data structure

The IFC data structure is divided into three structural areas:

- location structure,
- functional structure, and
- material structure.

First, the location structure (building site, floor, rooms with functions) is built up in the model, then the functional structure is incorporated into the spatial structure, and lastly the material structure is added. These three structures are linked by references. An instance of a functional element has links to the location structure (e.g., to IfcBuildingStorey) as well as to the material structure (IfcMaterial).

The consistent separation of these three structural parts is essential to provide a uniform structure, but this separation is not yet fully implemented. This can be seen, e.g., in the IfcElement class, for which information about the material properties can be entered via the Pset_ConcreteElementGeneral property set, whereas this should be reserved for the classes of the schema *Material Resource* of the *resource layer*. The consistent separation is intended to ensure that materials occur only once in the structure but can be referenced as many times as necessary.

With the upcoming IFC4.3, the functional structure will also receive a comprehensive supplement for the mapping of elements for transport infrastructure facilities (road and rail). With IFC4, significant additions (especially in the area of building services) for the complete mapping of building structures were already published in 2013. These are explained in detail below.

3.2.6 Domains and element classes

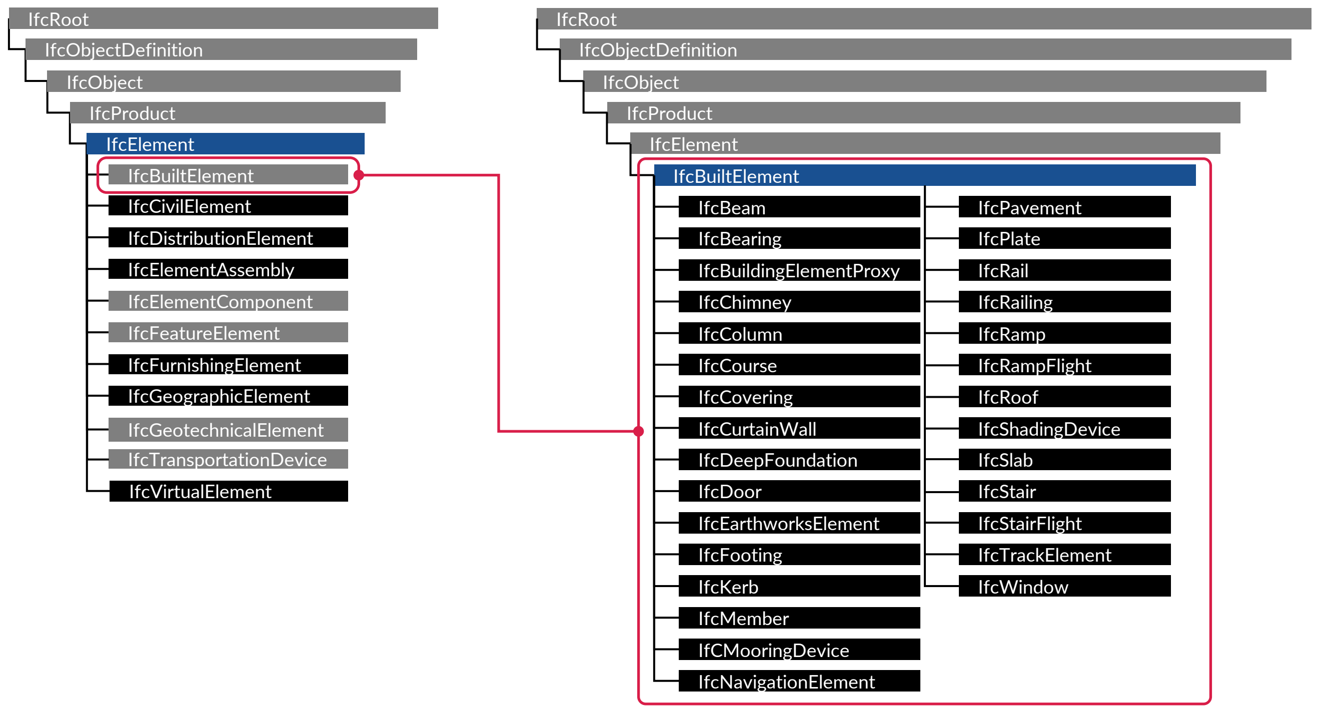
The functional element classes are used to represent buildings and are organised in domains (*domain-specific data schemas*) such as IfcArchitectureDomain or IfcHVACDomain (corresponding to the typical division of the planning trades). This declaration allows a clear assignment of responsibilities or filtering of model content during import or export. In addition, the *shared element data schemas* provide a parallel container of functional element classes that are used by several trades in parallel. An example of a functional element class is IfcSharedBldgElements, which is used to represent walls, slabs, columns and beams, among others. These are used by architects as well as for structural engineering.

The area of application of element classes is clearly defined. This is accompanied by a limitation of their geometric functionality (position, path, dimension), the attributes that can be derived from them (summarised in *Quantity Set*) as well as the characteristics that are necessary for its description (structured in *Psets*). In addition, the *material layer set* provides a specification for the assignability of materials for each element class. This can be, e.g., a layer-by-layer definition for IfcWall or a differentiation between the front, filling, and back for IfcCovering. The material declaration allows the free definition of materials, to which freely defined characteristics can be added. Although the IFC specification offers detailed predefined material characteristics, these have not yet been implemented in the BIM software applications. With the introduction of *DataTemplates* a change in the way building data (*IFC*) and product information (*DataTemplates*) are handled is to be expected.

The element class IfcBuildingElementProxy provides an element class for any area of application for which the IFC specification used does not yet have semantics – i.e., a suitable element class – or for which the BIM software applications used do not offer any support. For example, this class is currently frequently used in transport infrastructure projects that are processed using IFC2x3, as the current BIM software applications only offer stable support for this IFC version.

3.2.7 IfcElement and its subclasses

The basic component of the functional structure is the class IfcElement. IfcElement is a generalisation of all physically existing components that make up a structure. It is the superclass for a number of particularly important base classes which are necessary for the description of buildings. The following figure shows all the subclasses of IfcElement on the left side. In the context of building construction, the IfcElement subclass IfcBuildingElement is particularly relevant. In the following figure, the subclasses of IfcBuildingElement are shown on the right side, including elements such as IfcWall, IfcSlab, IfcColumn, IfcFurniture and IfcWindow.



Another subclass of IfcElement is IfcDistributionElement, which contains elements for distribution systems used in the MEP. These elements can be used for heating and cooling systems, waste water systems, and electrical systems, among others.

The IfcElement subclass IfcCivilElement, which translates into the IFC as the *civil engineering element*, was effectively introduced for infrastructure extensions. Currently, the class does not contain any subclasses and is merely a stub for incorporating a model for infrastructure projects that is under development. The intention is to introduce only elements that cannot be represented with elements IfcBuildingElement, IfcDistributionElement, and IfcGeographicElement of the IfcElement subclasses. These elements, which are organised horizontally, are found in the linear infrastructure assets of road, bridge, and rail construction. Horizontal organisation is accomplished using the IfcSpatialZone class, in which every IfcCivilElement is contained spatially by default. The IfcSpatialZone class is a subclass of IfcSpatialElement, which is a more general spatial zone compared to the IfcSpatialElement subclass IfcSpatialStructureElement. IfcSpatialStructureElement contains mainly building-specific classes like IfcSite which are hierarchical in nature.

3.2.8 Object relations – material assignment and spatial assignment

In addition to the functional structure, i.e., essentially the elements of the class IfcElement, the spatial structure, and the material structure are fundamental components of the IFC data model. The location of the elements in the spatial structure as well as the assignment of materials to the elements is done via the object relations function.

General concept of object relations

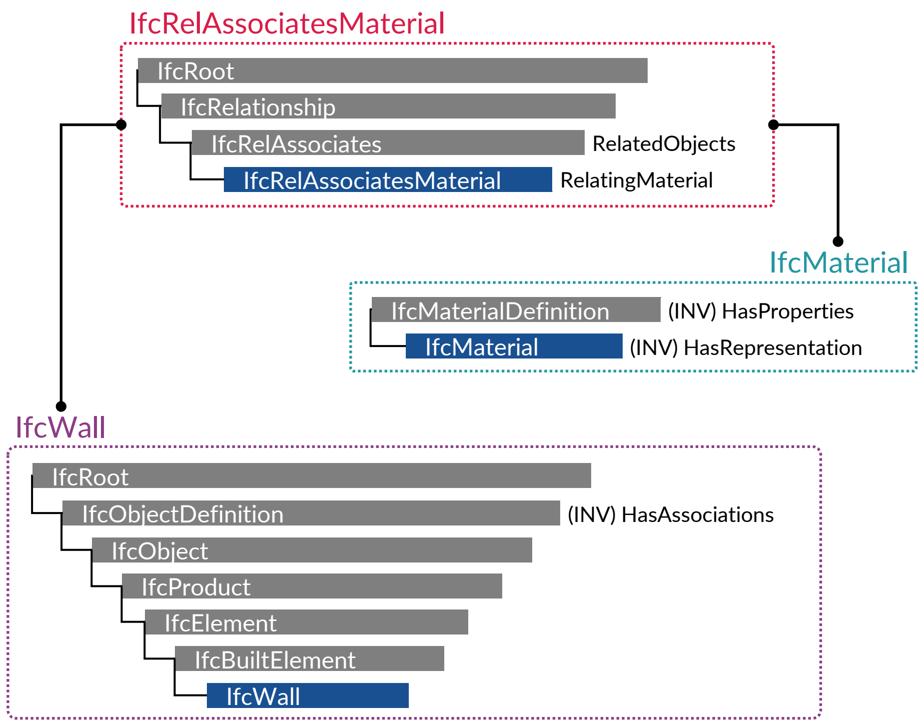
By means of the concept of object relations, components can be related to other objects. In the IFC, this is done using the principle of objectified relationships. This means that the association of two objects is established via separate, intermediate objects that represent the relationships. These relationship objects are always instances of a subclass of the IfcRelationship class, which belongs to the *kernel* in the *core layer*. The relationship objects are linked to the objects via attributes with names beginning with Related or Relating. The backward relationship is established via related inverse attributes.

Material allocation

The assignment of materials to components is an important part of every digital building model, as these are crucial for quantity determination, structural analysis, and energy demand calculations. The linking of components (i.e., subclasses of IfcElement) with materials (i.e., subclasses of IfcMaterialDefinition) is done via the relationship class IfcRelAssociatesMaterial. The superclass of this relationship class is IfcRelAssociates, the various subclasses of which establish relationships with different information external or internal to the project (material information in the case of IfcRelAssociatesMaterial).

For the relationship class IfcRelAssociatesMaterial, the following figure illustrates an example of a possible relationship. IfcRelAssociatesMaterial has the attribute RelatingMaterial and inherited from IfcRelAssociates also the attribute IfcRelatedObject. The former attribute references subclasses of IfcMaterialDefinition, such as IfcMaterial or even IfcMaterialLayerSet which is required for composite materials. The second attribute refers to subclasses of IfcObjectDefinition, such as IfcWall. The class IfcWall has the inverse attribute *HasAssociations* due to attribute inheritance. The linking achieved by means of the attributes is shown in the figure.

Materials can be named using the Name attribute. In addition, subclasses of IfcMaterialDefinition can be assigned further material properties, such as mechanical, thermal, or optical properties, via the inverse attribute *HasProperties*. Furthermore, the class IfcMaterial can be associated with representation information, such as hatchings in the 2D representation or information for renderings, via the inverse attribute *HasRepresentation*.

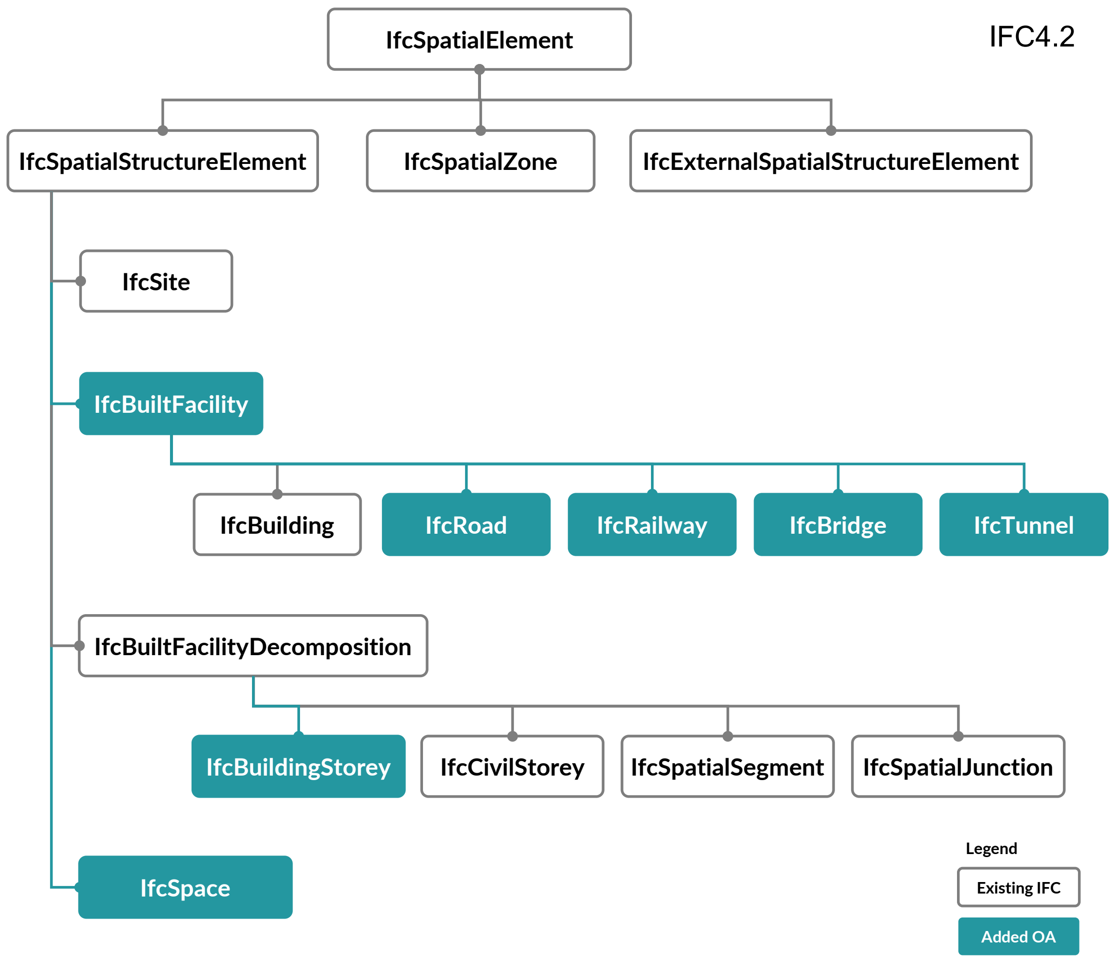


Spatial allocation, location structure

The spatial structuring of the components is fundamental for every building model. When creating a project, the so-called location structure is created first. Subsequently, the components are logically embedded in it.

The scope of the location structure was expanded considerably in IFC4.1. While previously it was possible only to describe structures in the area of building construction (even though it was sometimes also used for infrastructure projects), IFC4.1 contains a complete infrastructure addition. The following figure shows this modification. The noncolored structural components are existing building construction components while the turquoise components are the new infrastructure components.

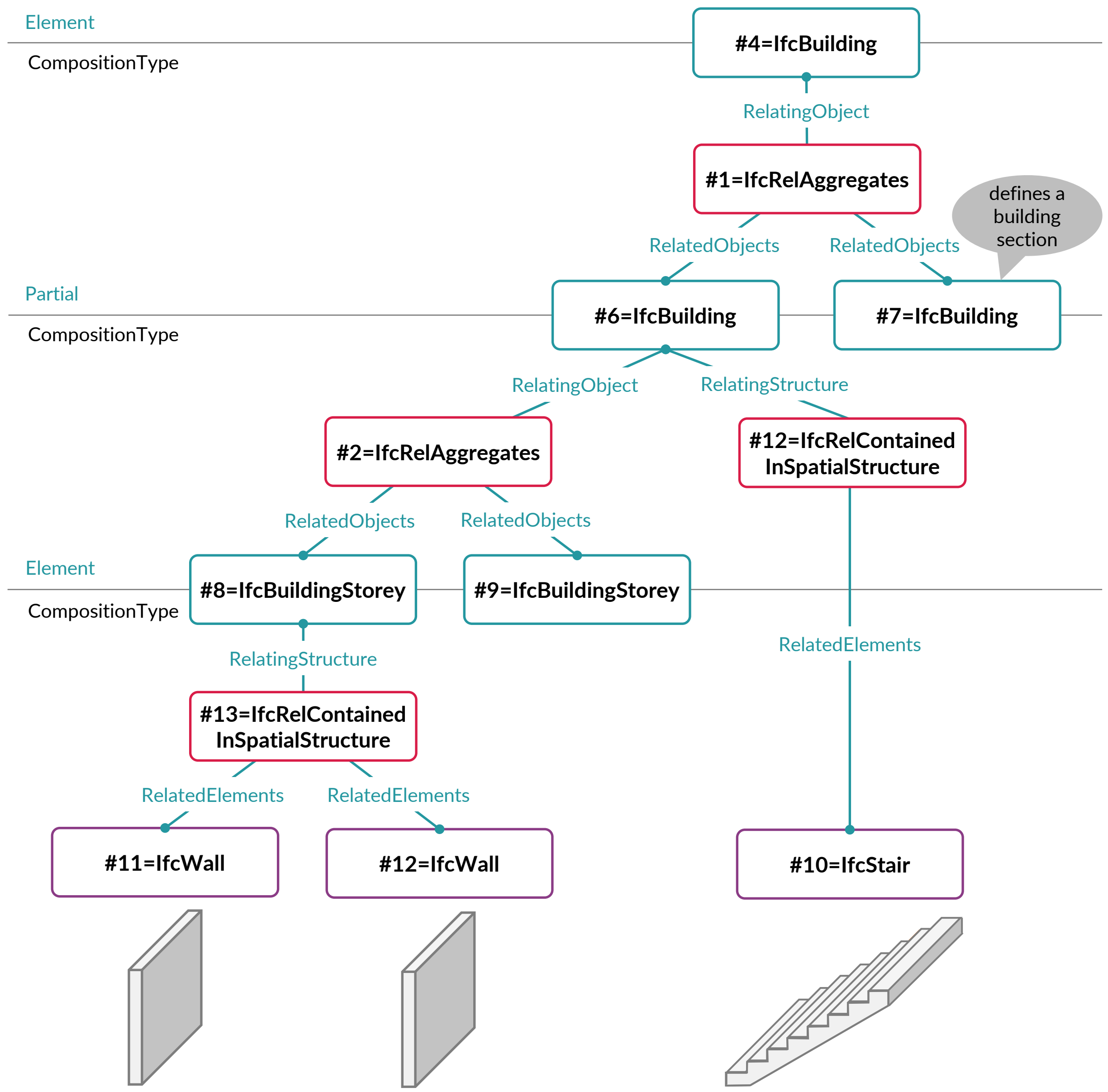
Initially, the additions were made at the IfcBuilding level – this has now been reorganised by IfcBuiltFacility into a group of different building types (IfcRoad, IfcRailway, IfcBridge, IfcTunnel). In addition, changes were made at the IfcBuildingStorey level. IfcBuiltFacilityDecomposition now also allows IfcBuildingStorey and IfcCivilStorey to be used to structure *civil engineering structures*, and IfcSpatialSegment and IfcSpatialJunction to provide corresponding options to map linear structures. The latter two structural components in particular have a significant impact on the applicability of IFC in the infrastructure sector, and comprehensive support for the mapping of route alignments has been implemented in the so-called »IFC alignment«.



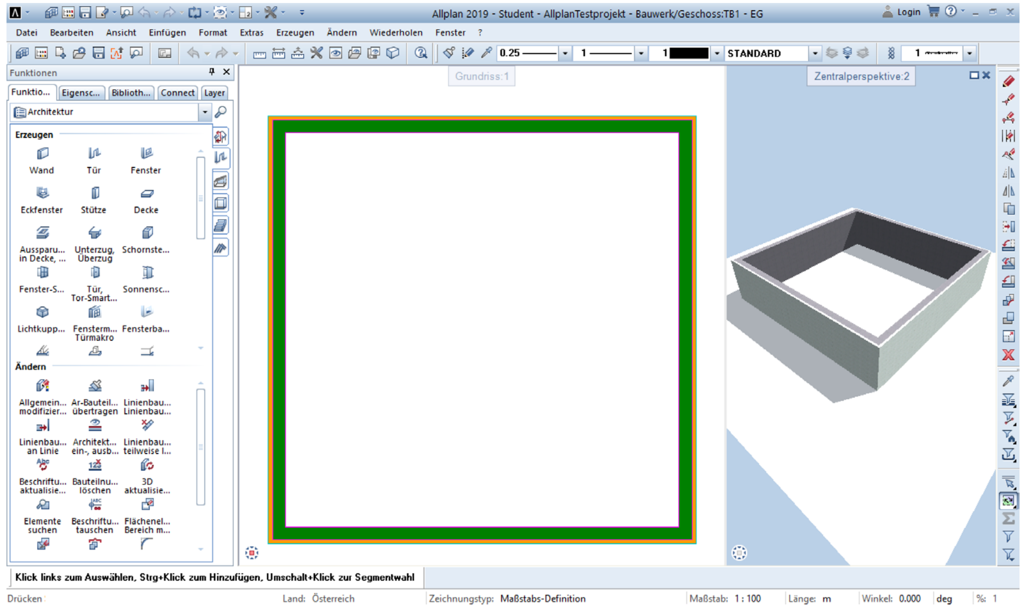
In IFC, the location structure consists of spatial objects. In the case of a building, the room objects are instances of subclasses of IfcSpatialStructureElement. These include the classes IfcSite, IfcBuilding, and IfcBuildingStorey (i.e., building site, building, and story). They are linked to a hierarchical project structure via relationship objects of the IfcRelAggregates class. An example of the linking of such room objects using IfcRelAggregates is shown below. The IfcRelAggregates relationship class, which is a subclass of IfcRelDecomposes, is used to link IfcObjectDefinition subclasses. In this particular case, it is used to organise several spatial objects into a spatial group.

The relationship class IfcRelContainedInSpatialStructure is used to assign components to the spatial objects. Two instances of this are also shown in the following figure. This class is a subclass of IfcRelConnects (see figure in »Other subclasses of IfcRelationship«). It is worth noting that each component can only be assigned to one spatial object. However, if a component, such as a cross-

story façade element, is associated with multiple spatial objects, this additional assignment can be made using the IfcRelReferencedInSpatialStructure relationship class. The linking of components to the relationship object is done using the inverse ContainedInStructure attribute of the IfcElement class. Consequently, elements of all subclasses of IfcElement can be linked to room objects. In the example shown, an instance of the IfcStair class is linked to a room object of the IfcBuilding class, and two objects of the IfcWall class are linked to a room object of the IfcBuildingStorey class.



In the following paragraphs, the mapping of relationships in an IFC file is illustrated with another example. For this purpose, four walls were modelled using Allplan 2019-1, each consisting of a reinforced concrete layer and a thermal insulation layer:

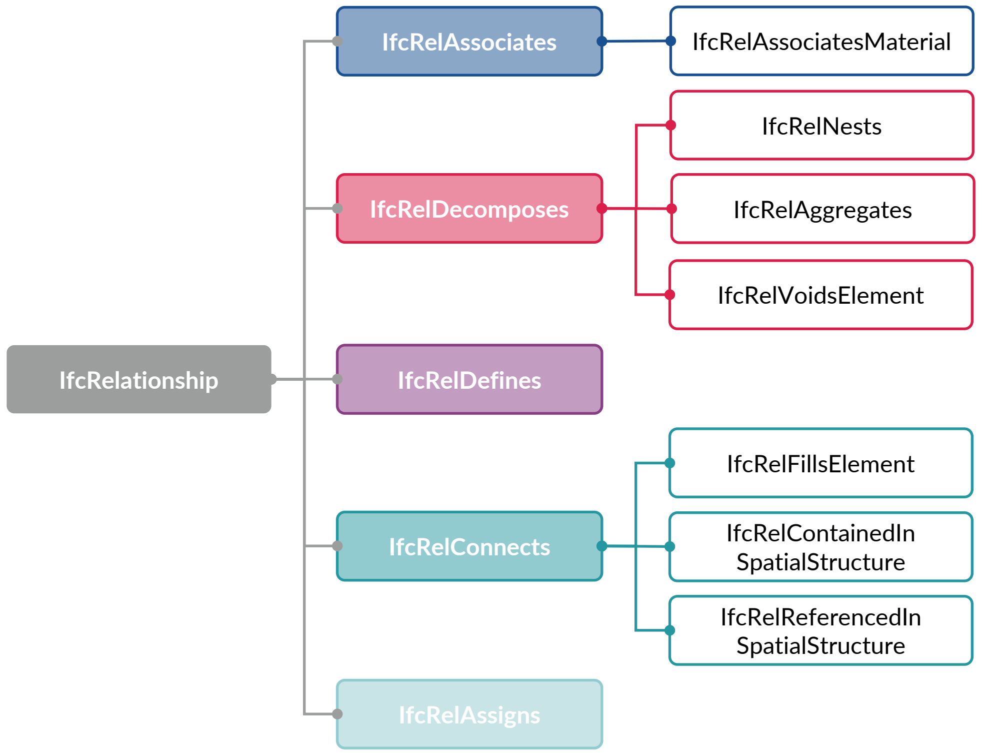


The following figure shows the IFC file exported from Allplan, opened in Microsoft Excel. Almost 90% of the rows of the DATA section are hidden and the remaining rows are highlighted for better clarity. Any information related to the properties of the walls and the materials assigned to them are hidden. The display thus contains only information about the spatial structure and the geometry of the objects and how they are linked to each other.

Instances colored yellow are related to the project structure and the room objects, those colored blue to the walls and their geometry. Instances colored gray are referenced across the board. The bottom two orange lines contain two instances of the IfcRelAggregates class. The first instance locates the object with IFC file internal identifier `#38` (the building of class IfcBuilding) in the project with ID `#26`. The second locates the floor of class IfcBuildingStorey (ID `#54`) in the building. The pink line above these two lines shows an instance of the IfcRelContainedInSpatialStructure class. It locates the four walls of class IfcWallStandardCase (with the identifiers `#198`, `#386`, `#546`, and `#710`) in the floor with ID `#54`. Since no rooms were modeled in the project and adjacent walls are not connected by relationship objects in IFC, their relative placement to each other can only be understood via their coordinates.


```
#11= IFCOWNERHISTORY(#7,#10,$,.NOTDEFINED.,$,$,$,1581848416);
#26= IFCPROJECT('3xUAvmkUzENPEaZ0_s0awJ',#11,'AllplanTestprojekt',$,$,$,$,(#65),#36);
#36= IFCUNITASSIGNMENT((#13,#14,#15,#19));
#38= IFCBUILDING('0wVmWt28TDpvgEtBzNOUSA',#11,'Default Building',$,$,#50,$,$,.ELEMENT.,$,$,$);
#47= IFCAXIS2PLACEMENT3D(#48,$,$);
#48= IFCCARTESIANPOINT((0.,0.,0.));
#50= IFCLOCALPLACEMENT($,#47);
#54= IFCBUILDINGSTOREY('2au4f2cLb9SQe_neNqe1FT',#11,'Geschoss',$,$,#58,$,$,.ELEMENT.,0.);
#55= IFCAXIS2PLACEMENT3D(#56,$,$);
#56= IFCCARTESIANPOINT((0.,0.,0.));
#58= IFCLOCALPLACEMENT(#50,#55);
#65= IFCGEOMETRICREPRESENTATIONCONTEXT($,'Model',3,1.000000000000000E-5,#21,$);
#68= IFCAXIS2PLACEMENT3D(#69,#71,#73);
#69= IFCCARTESIANPOINT((11013.29361463148,18449.9287310378,-200.));
#71= IFCDIRECTION((0.,0.,1.));
#73= IFCDIRECTION((-1.,0.,0.));
#75= IFCLOCALPLACEMENT(#58,#68);
#77= IFCPRODUCTDEFINITIONSHAPE($,$,(#126,#141));
#81= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,'',#84);
#84= IFCPOLYLINE((#86,#88,#90,#92,#94,#96,#98,#100,#86));
#86= IFCCARTESIANPOINT((-10000.,-400.));
#88= IFCCARTESIANPOINT((0.,-400.));
#90= IFCCARTESIANPOINT((0.,-300.));
#92= IFCCARTESIANPOINT((-100.,-300.));
#94= IFCCARTESIANPOINT((-100.,-0.));
#96= IFCCARTESIANPOINT((-9900.,-0.));
#98= IFCCARTESIANPOINT((-9900.,-300.));
#100= IFCCARTESIANPOINT((-10000.,-300.));
#102= IFCCARTESIANPOINT((-10000.,-400.));
#104= IFCEXTRUDEDAREASOLID(#81,#105,#112,2500.);
#105= IFCAXIS2PLACEMENT3D(#106,#108,#110);
#106= IFCCARTESIANPOINT((10000.,400.,0.));
#108= IFCDIRECTION((0.,0.,1.));
#110= IFCDIRECTION((1.,0.,0.));
#112= IFCDIRECTION((0.,0.,1.));
#126= IFCSHAPEREPRESENTATION(#61,'Body','SweptSolid',(#104));
#133= IFCPRESENTATIONLAYERWITHSTYLE ('Daemmung',$,(#104,#323,#483,#647),'MW_DAEMMUN',.T.,.U.,.F.,(#134));
#141= IFCSHAPEREPRESENTATION(#143,'Axis','Curve2D',(#145));
#143= IFCGEOMETRICREPRESENTATIONSUBCONTEXT('Axis','Model',*,*,*,*,#65,$,.MODEL_VIEW.,$);
#145= IFCPOLYLINE((#147,#149));
#147= IFCCARTESIANPOINT((0.,0.));
#149= IFCCARTESIANPOINT((10000.,0.));
#198= IFCWALLSTANDARDCASE('0MnkgC4Fv5kfTsvYU2Myo8',#11,' ',$,$,#75,#77,$,$);
#386= IFCWALLSTANDARDCASE('3QrME8v0LDvhhz5vzIpgYG',#11,' ',$,$,#299,#300,$,$);
#546= IFCWALLSTANDARDCASE('1lisxhtQb1$h2z4CM719Kf',#11,' ',$,$,#459,#460,$,$);
#710= IFCWALLSTANDARDCASE('1e7$owAd98_v64KEXwR6Pd',#11,' ',$,$,#623,#624,$,$);
#780= IFCRELCONTAINEDINSPATIALSTRUCTURE('0UVDK$JnLCkuGl5p_d2wxo',#11,$,$,(#198,#386,#546,#710),#54);
#787= IFCRELAGGREGATES('21HSISdH98seVOROFZ51BE',#11,$,$,#26,(#38));
#791= IFCRELAGGREGATES('2MWo5JTgv4HOO2$ZGD4AfV',#11,$,$,#38,(#54));
```

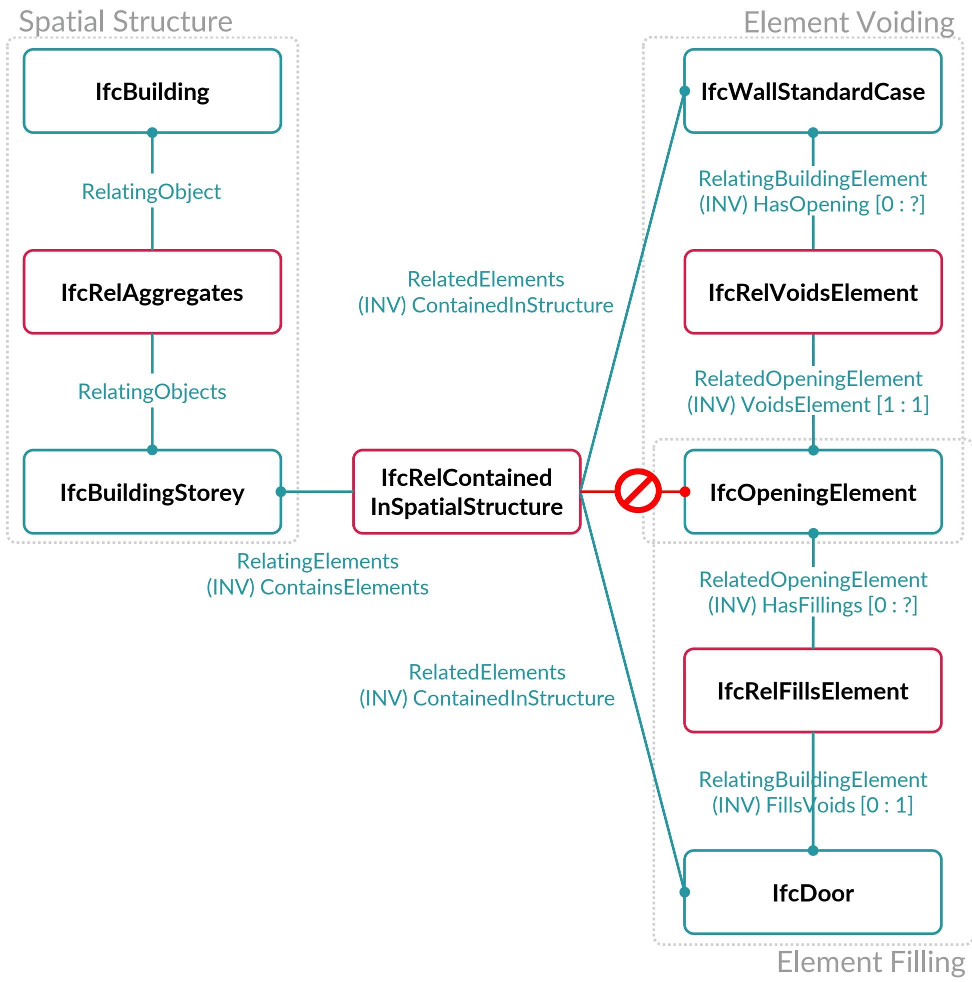
Other subclasses of IfcRelationship
The five direct subclasses of IfcRelationship and some of their subclasses are shown in the following figure:



IfcRelAssociates associates information sources for materials, documents, and restrictions located inside or outside the project data with objects of the classes IfcObject and IfcTypeObject, and in certain cases of the class IfcPropertyDefinition. Details about the IfcRelAssociates subclass IfcRelAssociatesMaterial can be found above in »Material allocation«.

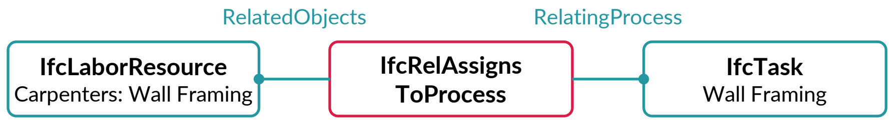
In IFC, IfcRelDecomposes is interpreted as a »part-to-whole relationship«. It defines the general concept of composite or decomposed elements. This relationship class can be used to formulate a part-to-whole hierarchy, with the ability to navigate from the whole (composition) to a part and vice versa. There are several types of decompositions, e.g., class IfcRelNests, which can be used to link cost elements where one forms a container (»*nest*«) for the others, and class IfcRelAggregates, which can be used to form a representation of a frame construction as a grouping (*aggregation*) of a beam and a column. This class is also used for linking spatial objects (see »Spatial allocation, location structure« above). Furthermore, class IfcRelVoidsElement provides the possibility to model an opening in an element. An instance of this class representing an opening in a wall can be found in the following figure.

IfcRelDefines contains subclasses for mapping object types to object instances (see Section 3.2.10), for mapping property sets to object instances (see Section 3.2.9), and for mapping *property set templates* to *property sets*.



IfcRelConnects contains classes that create connections between objects under special conditions. For subclass IfcRelContainedInSpatialStructure (see »Spatial allocation, location structure« above), the condition is that an object can be assigned only to a single spatial structure element. IfcRelReferencedInSpatialStructure is used to assign an object to another spatial structure element. The IfcRelFillsElement class allows a one-to-one relationship between an opening and an element that fills it, such as a door in a wall opening. This example is illustrated in the previous figure. The opening itself is linked only to the elements, i.e., the door and the wall in the example, and not to the spatial object in which it is located.

IfcRelAssigns is the superclass for various »link« relationships that can be used between instances of IfcObject and their direct subclasses. A »link« refers to the association where the object »Customer« (client) applies the services of the other object (»*Supplier*«). The following figure shows an example where an instance of the IfcResource subclass IfcLaborResource is assigned as a supplier to an instance of the IfcProcess subclass IfcTask as a client. The relationship object for this link is the IfcRelAssigns subclass IfcRelAssignsToProcess.



3.2.9 Properties

In order to implement an extension or specialisation of classes in IFC without creating new subclasses, it is possible to define properties of objects. In IFC, the properties are implemented in two ways: by *attributes* or *properties* (characteristics). This dichotomy was provided for in IFC because properties required by users are not always internationally standardised and predictable. However, the schema should not be inflated any further. Attributes are used to store basic properties of objects directly in the schema. An example of this is the attribute *OverallHeight* of the class IfcDoor, which can be specified when instantiating a door object. Attributes are static and thus cannot be generated by users. The dynamically generated properties have opposing characteristics. They offer the possibility of national or user-specific extensions to the IFC schema.

Properties can be defined freely using the subclasses of IfcProperty, from the *Property Resource* schema of the *resource layer*. They are defined using a tuple of the form »name-value-datatype-entity«. The most commonly used subclass of IfcProperty is IfcPropertySingleValue, where exactly one value can be specified. The template for properties of the IfcPropertySingleValue class is »Name-NominalValue-Type-Unit«. For example, property IfcLoadBearing of class IfcWall is defined with the tuple »Name: Load Bearing; Value: YES; Data type: Boolean«. Another subclass of IfcProperty is IfcPropertyEnumeratedValue, where a value can be selected from predefined options which are referenced via the *EnumerationValues* attribute. Using the subclass IfcPropertyBoundedValue, the attributes *UpperBoundValue* and *LowerBoundValue* can be defined.

Individual properties are grouped in property sets (property lists). These property sets (Pset) are arranged thematically. Each element class includes at least one standard Pset, which is typically designated with the suffix Common, e.g., Pset_CoveringCommon. Some Psets (e.g., Pset_Warranty) are assigned to several element classes at the same time. For some years now, it has been the custom for individually created Psets to be designated with the suffix Specific, e.g., Pset_CoveringSpecific.

The class IfcPropertySet has the attribute *HasProperties*, which establishes the link to the class IfcProperty. This provides a kind of »metamodel« that can be further declared by populating the name attribute of the property set and the attributes of the associated properties.

The superclass of IfcPropertySet is the class IfcPropertySetDefinition; this is a part of the IfcKernel in the core layer. Apart from the dynamically extendable property lists of the IfcPropertySet class, it also defines statically defined property lists of the IfcPreDefinedPropertySet class. The few predefined property lists contain only attributes for architectural elements, such as the IfcDoorLiningProperties list, which can be assigned to the IfcDoor element and contains specialisations for door frames.

Chapter 3 – In-depth knowledge
3.2 IFC – industry foundation classes

A property set is linked to an object via the IfcRelDefinesProperties relationship object (see Section 3.2.8). Property sets are linked to the relationship object via the *DefinesOccurrence* attribute of the IfcPreDefinedPropertySet class. The attribute *IsDefinedBy* allows all subclasses of IfcObject to be linked to the relationship object. An assignment to an object type of class IfcTypeObject (see Section 3.2.10) is also possible and can be done directly via the attributes *DefinesType* or *HasPropertySets*.

In the database of the bSDD they are managed in the form of XML files with the naming scheme »Pset_.xml«.

Units

The declaration of IfcValue (e.g., IfcVolumeMeasure) can be used to precisely control the characteristics regarding the content, units, or value ranges to be used. Besides the measurement unit, the specification is usually also defined, e.g., the restriction to real numbers. With the attribute *ValueTypes*, the IFC specification includes a comprehensive definition of all existing SI units (see QR code).

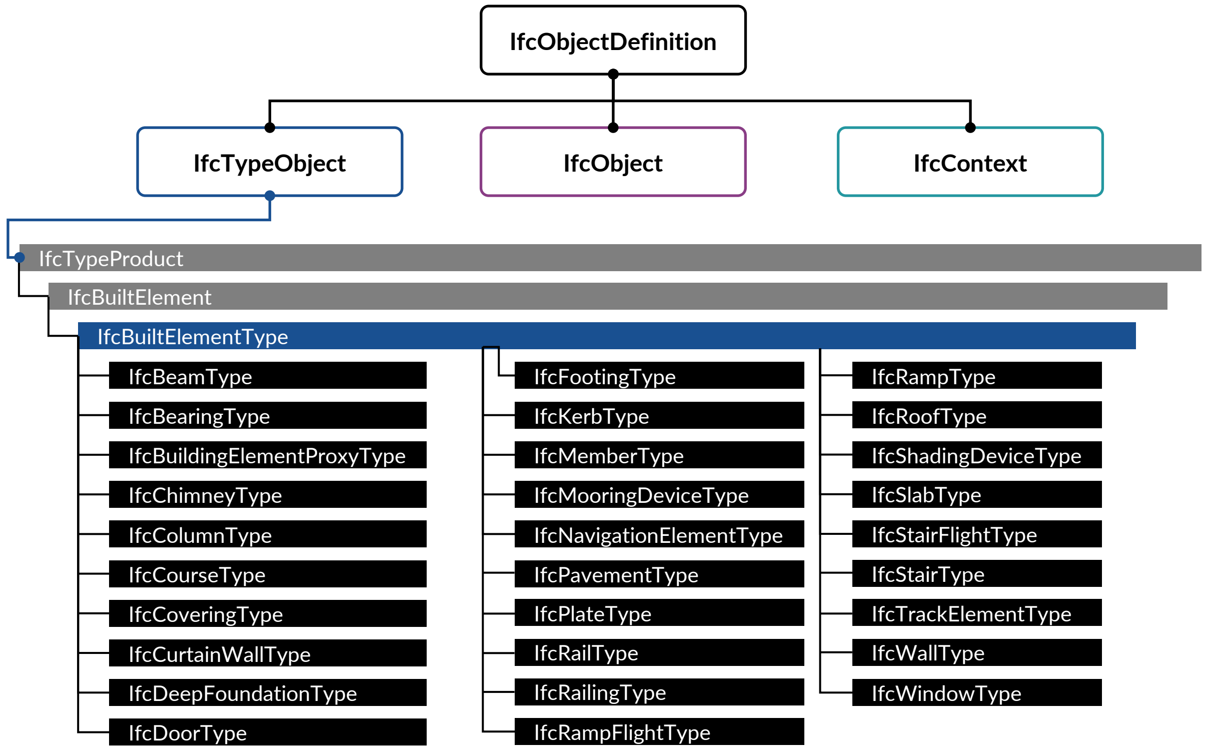
3.2.10 Object types

In IFC, the concept of object types is provided to efficiently describe repeatedly used components. To do so, a reusable pattern, a kind of template, is predefined. The object types can define attributes and properties, which are then passed on automatically to the linked objects. This is referred to as pre-instantiation. When the object types are instantiated, only data, such as spatial location or relationships to other objects, is specified. This data cannot be specified via object types.

All object types are subclasses of IfcTypeObject, whose superclass is IfcObjectDefinition, which is also the superclass of IfcObject. For most objects there are corresponding object types available, which have the same name as the object but are suffixed with »*Type*«, e.g., IfcDoorType to the object IfcDoor. The subclasses of the IfcTypeObject subclass IfcBuildingElementType are shown in the following figure.

For a covering (IfcCovering), there could be the following type declarations: *Ceiling*, *Flooring*, and *Insulation*. Some element classes such as IfcWindow, IfcDoor and even IfcPile have multiple type declarations. The type declarations for IfcPile include, e.g.,

- *PredefinedType* with the enumerations (IfcPileTypeEnum) BORED, DRIVEN, JETGROUTING etc., and
- *ConstructionType* with the enumerations (IfcPileConstructionEnum) CAST_IN_PLACE, COMPOSITE, PRECAST_CONCRETE, etc



However, such a concept will no longer be used in future versions of IFC, as it will become obsolete with the capabilities of multityping in IFC4.3. Multityping allows multiple types to be declared simultaneously. Up to IFC4.2, only single declaration of types was possible.

3.3 MVD – Model View Definition

The model view definition (MVD) is an essential basis for describing transfer requirements as well as their technical implementation. The implementation and certification of IFC in BIM software applications is based on MVDs.

3.3.1 Benefit of MVDs

An MVD is created in the context of a transfer requirement, e.g., for the coordination of different domain models. It defines a *subset* of the IFC specification (IFC schema). This subset focuses on the requirements (*exchange requirements*) of both the creator and the recipient of the information. The requirements are elicited on the basis of an IDM (information delivery manual) in accordance with ISO 29481. The delimitation of the IFC specification by means of an MVD can affect the following content:

- element classes and types and
- quantity sets, Psets, and characteristics.

The integration of the infrastructure requirements into the IFC specification causes an increase in the required element classes. It is becoming increasingly difficult to implement the entire IFC specification in BIM software applications, which is why it is useful to have the restrictions of an MVD. MVDs allow the functional scope of BIM software application to be tailored to the requirements

relevant to the MVD. Therefore, the certification process of buildingSMART for BIM software applications (see QR code) is based on MVDs. MVDs have a harmonising or consolidating effect on the software market, as they represent a kind of template for the required scope of functions in information creation, transfer, and interpretation.

3.3.2 Established MVDs and their objectives

Coordination View 2.0 (CV 2.0) was the first MVD to establish itself on the market of BIM software applications. It was developed in the context of IFC2x3 TC1 (2.3.0.1). The scope of CV 2.0 is the provision of domain models (architecture, structural engineering, building services engineering) for the overall coordination of building construction projects during the planning phase.

Download of CV 2.0

The geometric transfer options are not overly restricted and allow flexible adaptation. Model content can be transferred both with extruded geometry and with precise geometry (BREP – *boundary representation*). Transfer with extruded geometry allows the best possible native reuse in the target application. In contrast, transfer with precise geometry (BREP) allows exact geometry reproduction in the target application. In BREP mode, components can be broken down into their constituent parts (e.g., wall layers) and output as individual parts (components). In this way, the layer-by-layer evaluation/analysis of a model is possible. In IFC2x3, complex geometries are triangulated to be transferred.

CV 2.0 has been certified for many BIM software applications on the market and is currently the most widely used MVD. Due to a lack of alternatives, it is sometimes also used for transport infrastructure projects on an interim basis, with IfcBuildingElementProxy being improvised due to infrastructure element classes not yet being available or implemented in advance in the BIM software application. The fact that the location structure (SpatialStructure) has been developed mainly for above-ground construction (neglecting, e.g., infrastructure) and the imprecise handling of the coordinate system of the BIM software applications (in interaction with IFC) are frequently encountered problems.

Reference View 1.2 (RV 1.2) is the second established MVD. It was developed in the context of IFC4 ADD2 TC1 (4.0.2.1). RV 1.2 focuses on the provision of domain models as a reference (architecture, structural engineering, building services engineering) for the overall coordination of building construction projects during the planning phase.

In contrast to CV 2.0 the *geometric transfer options* are limited and geared toward the use case of model coordination. The model content is transferred with precise geometry (BREP – *boundary representation*). This allows for an exact geometry reproduction in the target software application. In BREP mode, components can be broken down into their constituent parts (e.g., wall layers) and output as individual parts (components). In this way, the layer-by-layer evaluation/analysis of a model is possible. IFC4 ADD2 TC1 (4.0.2.1) now also offers geometry description using NURBS for BREP, which is much more precise and space-saving (data volume) than the triangulation methods of IFC2x3.

As of December 2020, RV 1.2 has been certified for six BIM software applications on the market – but only for IFC export. Due to a lack of alternatives, it is sometimes also used for transport infrastructure projects on an interim basis, with IfcBuildingElementProxy being improvised due to infrastructure element classes not yet being available or implemented in advance in the BIM software application. The fact that the location structure (SpatialStructure) has been developed mainly for above-ground construction (neglecting, e.g., infrastructure) often poses a problem. The certification of RV 1.2 is less tolerant to errors; therefore, the execution of RV 1.2 certifications takes more time than those of CV 2.0 certifications. However, it can be assumed that RV 1.2 certifications provide a much more homogeneous implementation quality for the BIM software applications.

3.3.3 Future MVDs and their objectives

Since RV 1.2 implements the use case of model coordination in a much more focused manner than CV 2.0, at least one more MVD for IFC4 is required that supports the use case of model transfer (*interoperability*). This is necessary, e.g., for the provision of the architectural model to the structural engineer so that she/he can build a structural model. This MVD is also required for the transfer of the model to the client at the end of the project so that the client can subsequently update the model with any changes made to the structure.

Design Transfer View 1.1 (DTV 1.1) has been developed for this purpose. It has been developed as part of IFC4 ADD2 TC1 (4.0.2.1). The limitation of DTV 1.1 focuses on the transfer of domain models between two BIM applications – but only in one direction and not in a round trip. Geometric transfer capabilities are limited (unlike CV 2.0) and focused on the model transfer use case. Model content is transferred with extruded geometry and limited functionality. This allows for native reuse in the target application. DTV 1.1 is currently not certified for BIM applications (status 01/2023).

Quantity Takeoff View 0.1 (QV 0.1) is an MVD aimed at the model-based mass and cost calculation use case. This is currently under development (draft status) and is not yet certified for BIM applications (status 01/2023).

The Basic FM Handover View (FM) is an MVD aimed at the use case of data transfer of model information to FM (Facility Management) at the end of the project (see QR code). It has been developed in the context of IFC2x3 TC1 (2.3.0.1). The status of FM is »official«, but is not yet established on the market and not yet certified for BIM applications (as of January 2023).

The Product Library View 0.1 (LV 0.1) is an MVD aimed at the transfer of digital product information (data templates). This is currently under development (*draft status*) and is not yet certified for BIM applications (as of 01/2023).

3.4 BCF – BIM Collaboration Format

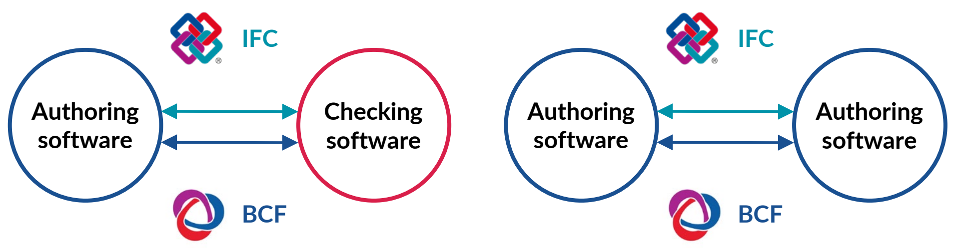
BCFs identify questions and problems regarding dedicated model elements and serve to communicate the deficiencies between the BIM organisational units. In the interaction between the ISO and buildingSMART standards, the BCF assumes the role of data interface for communication without transporting actual model elements.

BCF (or BCF comments) always contain:

- the GUID (*globally unique identifier*),
- the assigned name,
- stored viewpoint(s) with camera position on selected model elements, and visibilities and colorings of model elements (IFC coordinates),
- images (in relation to viewpoints),
- annotations in 3D space,
- description, date, author, addressee, group assignment (e.g., domain or BIM organisational unit),
- comments (author, date, viewpoint),
- attached files, and
- the status (e.g., open, closed).

As a standardised XML file (file extension ».bcf« or ».bcfzip«), a BCF does not contain the model or parts of it but establishes a reference relationship to model elements via their GUID. The GUID is an automatically generated number with 128 bits; it is unique and cannot be changed.

Their simple format allows software manufacturers to easily integrate the functionality into the relevant software applications. BCFs are used by all BIM organisational units. Their main scope is in the area of quality assurance of model management, since they communicate and document problems at the same time. However, BCFs are also used in small coordination cases between BIM domain coordination (*BFK*) and BIM author (BA) in order to be able to coordinate questions about model and planning content:



In addition, the BCF can have different uses in the various performance phases:

In the design phase:

- quality assurance/quality control (QA/QC) documentation,
- identification of design coordination problems (collision detection) between domain models, and
- comments on design options, object alternatives, and materials.

In the tender and award phase:

- coordination of the tender and clarifications and
- cost and supplier information for objects, assemblies, and/or systems.

In the construction phase:

- quality assurance/quality control (QA/QC) of installation records,
- tracking the availability of items/materials and coordinating substitute products, and
- collection of last-minute information for the transfer to owner/operator.

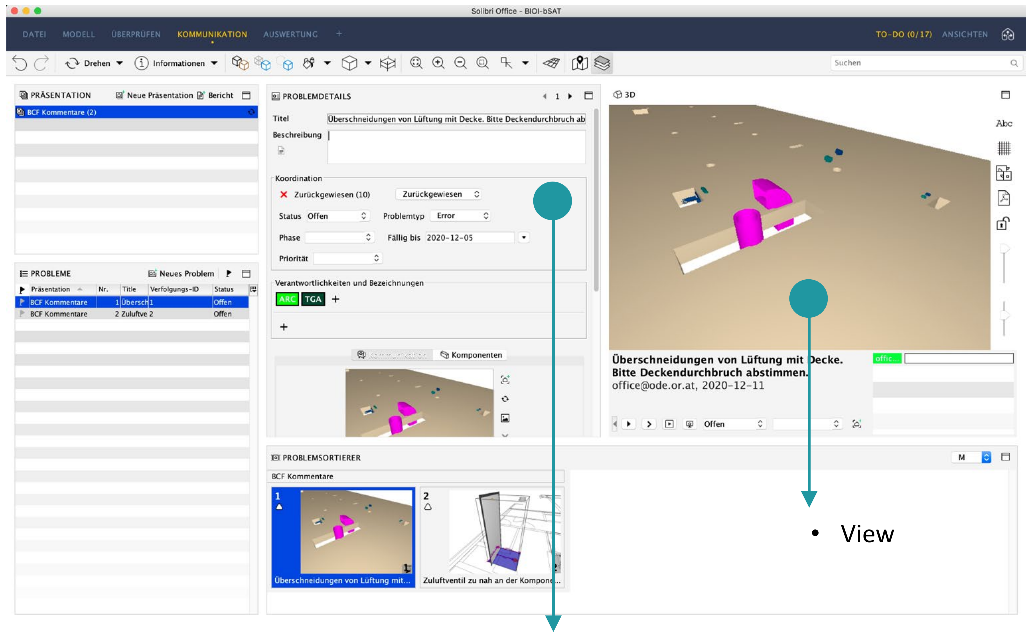
In the operating phase:

- notes on handover models in the event of changes to the plant and its many elements during operational use, and
- owner's notes on improvements needed.

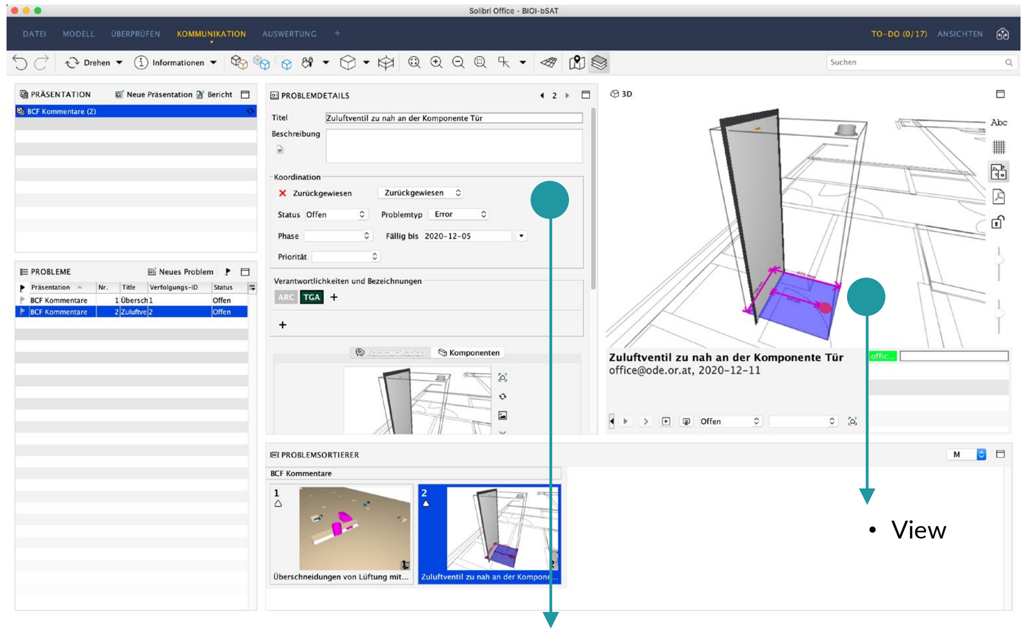
The comments in BCFs should always be precise, brief, and value-neutral. The selected views of the model content should always be clearly displayed (by visibilities and colourings). The status of BCFs should always be kept up to date. When included problems have been solved, the status should be set to »closed«. These guidelines facilitate a good workflow between all project participants and ensure that the BCF functionality can also be used effectively in other software applications.

In the interests of transparency and consistency, BCFs should always be exchanged via a defined platform, regardless of when and how they are used. This can be the CDE of the respective project or an additional web-based collaborative platform intended for this purpose. A good platform also provides a good overview of the status of a project via its functionalities and representations – this can be mapped via the BCFs. By assigning them to groups (BIM organisational units and domain models), to responsibilities in the issues and to the status of all BCFs, it is not only possible to identify individual critical points but also to map critical project performance in good time.

The following figures show typical BCF comments. The problem description, the status, the due date, as well as the responsibility are located in the central area. Shown on the right are the corresponding views (viewpoint with camera position onto selected model elements).



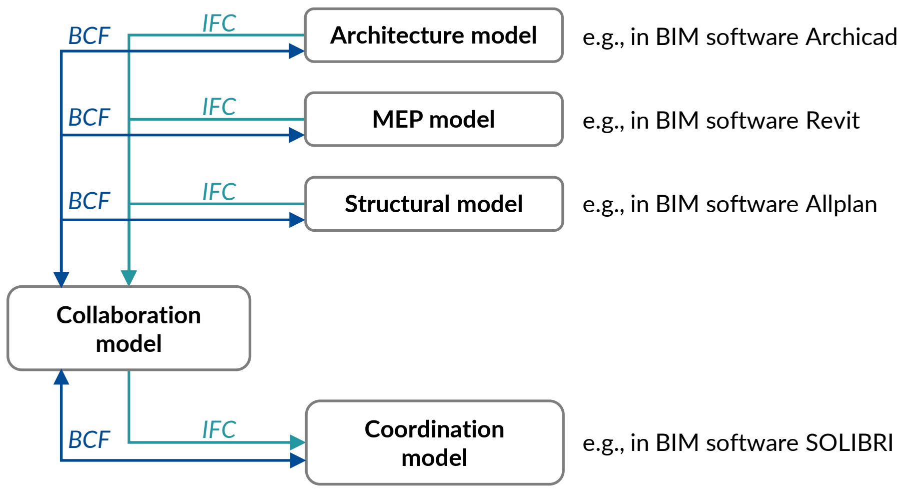
- Problem description
- Status
- Due date
- Responsibility



- Problem description
- Status
- Due date
- Responsibility

3.5 CDE – Common Data Environment

The common data environment (collaboration platform) is an essential basis for handling collaboration in the course of project implementation. In projects, a CDE is usually provided by the client. In the best-case scenario, a professional client handles its entire portfolio on a CDE, thus reducing setup costs while benefiting from the advantages of central data storage and uniform structuring.



A CDE is generally understood to be a web-based platform for collaboration across the entire planning team – this facilitates collaboration between different software applications. For the implementation of collaboration within a domain, integrated collaboration platforms are used – these permit collaboration within a specific application and offer options such as real-time collaboration and joint working down to the element or even feature level.

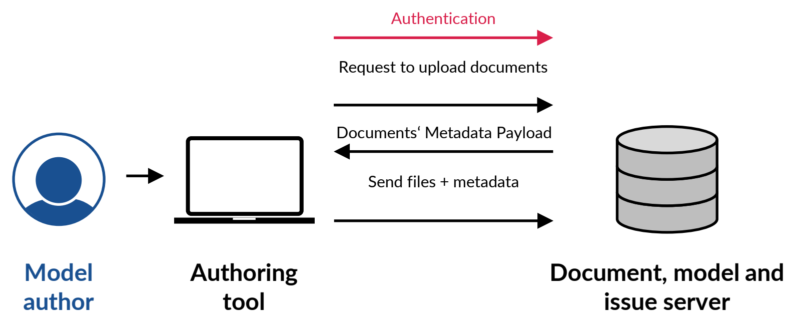
3.5.1 History of development

In 2007, the function and structure of a CDE was described for the first time in the British BIM standard PAS 1192. It assumed collaboration on a file basis – which can be realised with simple file-sharing platforms (e.g., Nextcloud). The status of a file was to be declared by being assigned to a folder (*Work In Progress*, *Shared*, *Published*, *Archived*).

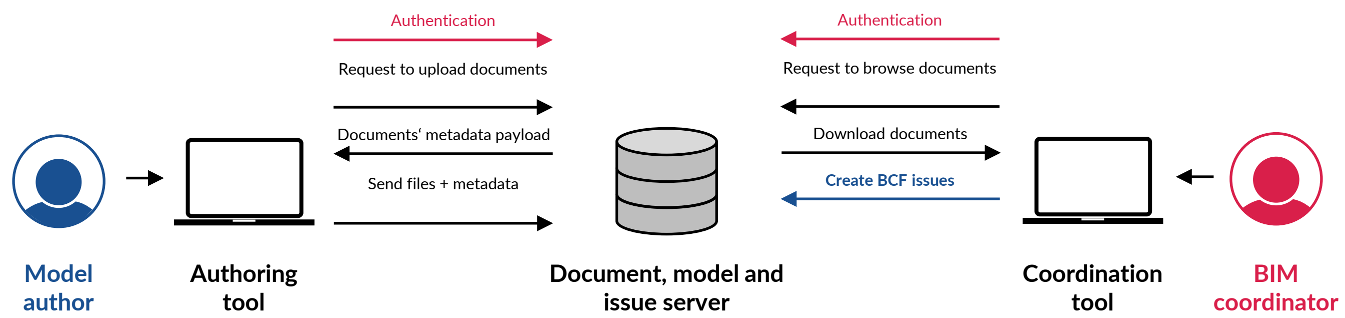
ISO 19650 defines the CDE as the central component of a PIM (*project information model*) in which all project information is collected, exchanged, and transferred to the AIM (*asset information model*) for project completion. The underlying structure was taken from PAS 1192, as the ISO 19650 series is based on this standard.

Currently available CDEs offer a significantly more complex range of functions with the integration of project-related (e-mail) communication, file/plan exchange, model/comment exchange, and viewer function. The implementation of the original concept of PAS 1192 is nowadays often realised via status information and file versioning to allow the interaction with workflow functionalities.

The weak point of CDEs in practice is the high effort involved in providing information. The parties involved have to upload documents, plans, models (IFC), and model comments (BCF) more or less manually to the CDE and declare them accordingly. This sometimes (product-dependent) laborious work is time-consuming and error-prone. The following figure describes the typical effort involved in providing model information in the CDE (top) and in checking and providing the check results (bottom):

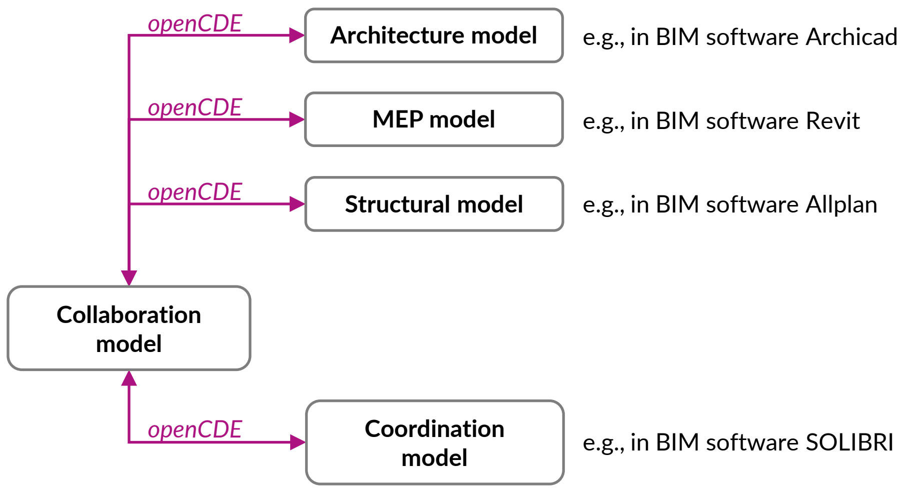


adapted from Kulbak, Paasiala



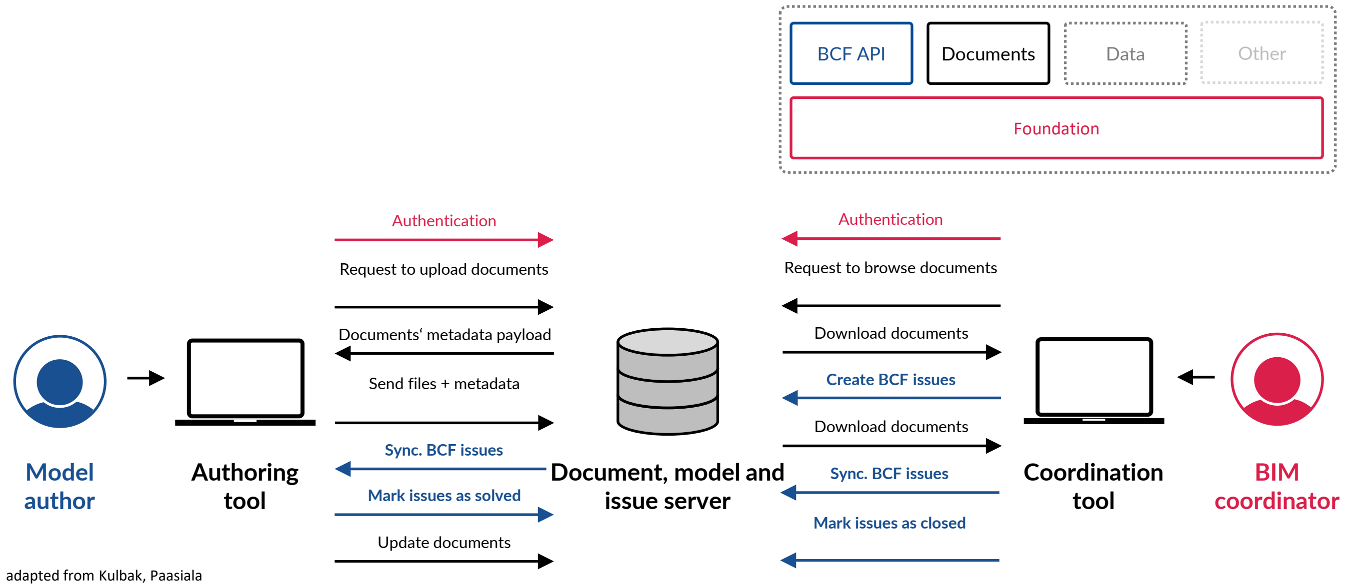
adapted from Kulbak, Paasiala

These disadvantages will be eliminated in the future by using a web-service-based connection of the software applications to the CDE – this technology is currently being developed under the name openCDE (see QR code).



In openCDE, the exchange will no longer be handled at the file level but on the basis of database-driven web services. Manual declarations will no longer be required; only changes will be transferred. This optimises the data volume and thus the transfer time. The following figure illustrates the reduced effort in model-based communication (processes marked in bold).

This technology has already been used in the BIMcollab communication platform, which connects BIM applications to the BIMcollab server using special add-ons. With openCDE, this technology can now be used for all CDEs.



adapted from Kulbak, Paasiala

3.5.2 Objectives of a CDE

The objectives of a CDE are

- the creation of a unique data environment for a project and its project team, or a data environment for a complete portfolio of various projects and their respective project teams,
  advantage: rapid availability of information, unambiguous retrievability of information, central evaluability of all projects (for portfolio);
- ensuring the necessary data security through encrypted data transmission, user authentication, multiclient capability, role-based user concept,
  advantage: ensuring the necessary discretion over sensitive information, guaranteeing compliance with legal requirements;
- the consistent and uniform structuring of all project information (also across projects),
  advantage: easier project management due to the easier evaluation of project status, easier comparability of project information;
- the uniformly controlled implementation of project processes (also across projects),
  advantage: simplified project management due to predefined processes with clear responsibilities and traceable communication.

- fast and accurate collection of the project status via predefined characteristic values (also across projects),
  advantage: facilitated project management;
- facilitated identification of relevant project content/procedures for archiving or for compact transfer of relevant project content/procedures for archiving upon project completion; and
- facilitating the identification of relevant project content/processes for operations management or compact transfer of relevant project content/processes to operations management or the AIM at relevant times.

3.5.3 Criteria for CDEs

A CDE is a central data room for all project information. Its operation is therefore subject to data protection criteria and the warranty claims that must be taken into account. The CDE is often made available on the provider's hardware because the customer does not have the necessary technical capacity and security in its own IT structures. In such cases, the client must check both the conformity of the provider's service with data protection law and its conformity with the required warranty claims for availability, fail-safety, physical access, incompatibility of the dependency on third parties, etc. Such requirements are often not fulfilled in currently advertised cloud offerings, and the advantages and disadvantages must be carefully examined.

3.6 LOIN and levels of detail (LOG, LOI)

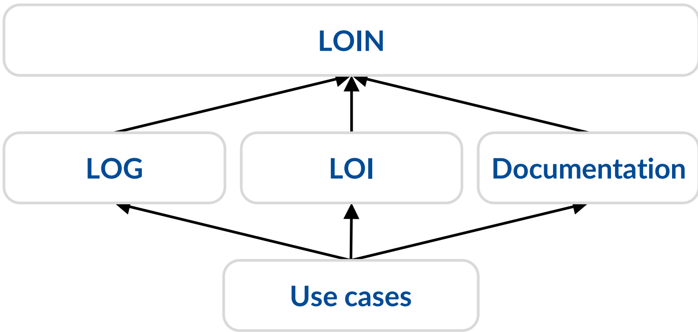
This section describes the content and relationships of the levels of detail. They are an essential part of the technical guidance within the EIR and BEP regulations. The levels of detail are part of a company's requirements and serve as a basis for the smooth running of a project – however, they are not standardised. In particular, the LOG and LOI levels of detail are mandatory in the EIR and BEP regulations as specifications for model data implementation and data delivery. Both levels of detail are part of the normatively defined LOIN (EN 17412-1).

The individual levels of detail in Austria are:

LOIN – Level of Information Need describes the client's requirement for the depth of geometric and alphanumeric information. Both requirements are derived from the use cases in the project, so the specific information requirement is defined by the need in a use case. This avoids that the LOG and LOI contain too much (unnecessary) or too little (overlooked) geometric or alphanumeric information. Furthermore, the LOIN requires the exchange of the corresponding documentation, as the LOIN should be readable by both humans and machines.

LOG – Level of Geometry refers to the geometric requirements for the representative representation of building elements or their detailing. The specifications of the LOG give users of BIM software precise guidelines on the level of detail of the building elements of a planning model depending on the project phase.

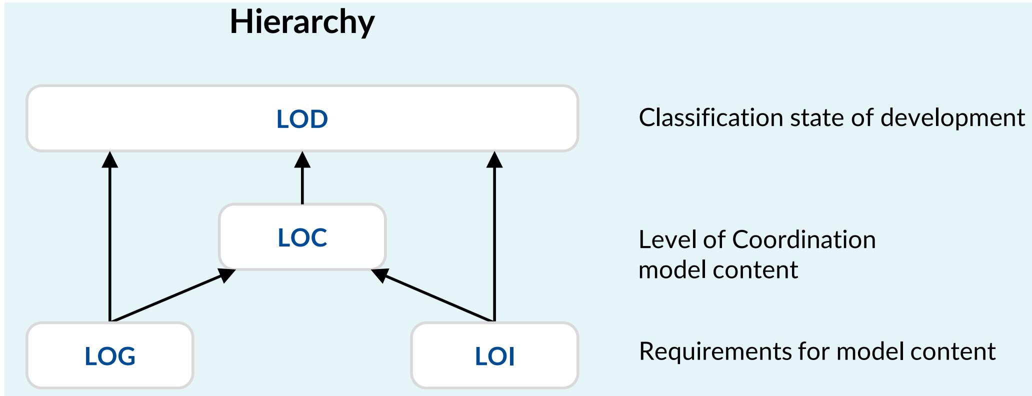
LOI – Level of Information refers to the alphanumeric requirements for building elements. The specifications of the LOI give users of BIM software precise guidelines on the level of information of the building elements of a planning model depending on the project phase.



An example of the relationships shown is the use case of quantity and mass determination in openBIM projects:

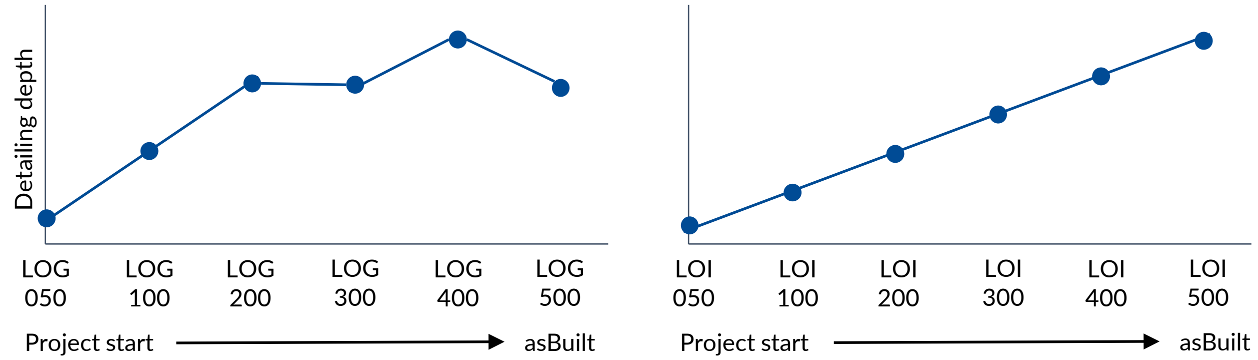
The use case specifies that the quantities and masses of reinforced concrete slabs are taken from the structural engineering model, including the reinforcement. For the LOI it is defined that the reinforcement ratio is contained in the property ReinforcementVolumeRatio of the property set Pset_ConcreteElementGeneral. The geometric formulation (LOG) does not contain any modelled reinforcement in the reinforced concrete elements. In order to be able to compare the reinforcement with the calculations in a calculation software, a list of reinforced concrete slabs including the contained reinforcement ratio is requested as documentation.

(Outdated status: LOD = LOI + LOG)
The classification of the development status of the model data was previously controlled by the Level of Development (LOD). For this purpose, the Level of Coordination (LOC) was required, which represents the degree of coordination of the discipline-specific model data in relation to the phases. With the introduction of LOIN (Level of Information Need) in EN 17412, the first mappable level of information need was introduced. Through its concrete reference to use cases, LOI and LOG, the level of elaboration or coordination can now be queried and checked in a different way. When using LOIN in projects, the use of LOD and LOC is not necessary.
LOD – The level of development describes the project-phase-related level of development of components. It is made up of the LOC, the LOG, and the LOI of the components.
LOC – The level of coordination provides information about the level of coordination of a building element depending on the project phase. It is determined internally (per domain) and superordinately (across domains) via the LOG and LOI to be used. The LOC can assume only two values, namely »true« or »false«.
The levels of detail are hierarchical and directly related to each other as shown in the following figure:



The LOG and LOI are the best known of the levels of detail. They define the specific information requirements of the client that need to be implemented by the project participants. The EIR contains the basic set of information requirements that can be modified in the BEP on a project-specific basis. The content of both levels of detail should be examined in detail at the beginning of the project and discussed in terms of feasibility and responsibility.

The development of the level of detail of the LOG and the LOI can be abstracted as shown below:



While the level of detail of the alphanumeric requirements in the LOI increases steadily, the level of detail of the LOG may remain partially constant (e.g., during LOG200 for design and LOG300 for submission planning) or may even decrease at the time of handover of the as-built model to Facility Management.

Specifically, the levels of detail of the LOG and the LOI define for the model content WHAT > HOW + WHEN + WHO must be transferred:

- WHAT establishes the element reference via the IFC entity,
- HOW describes the information request,
- WHEN 050 to 500 is mapped in a phase-related manner by LOG and LOI classes, and
- WHO is defined by the responsible domain.

The following example from the EIR of buildingSMART Austria describes the requirements of LOG classes 050 to 500 (in German):

LOG-Klassen AR-Modell

Nachfolgende Tabellen beschreiben die LOG-Klassen der IfcArchitectureDomain[30].

	Phasenbezug					
LOG-Klasse	**LOG050**	**LOG100**	**LOG200**	**LOG300**	**LOG400**	**LOG500**
Raumstempel/ BGF	Jede Einheit als Volumenkörper zur Definition von BRI/BGF	Jeder Raum als IfcSpace zur Definition der NRF gem. ÖN B1800 / SIA416 BZW. D0165. Geschossweise getrenntes Gebäudevolumen als IfcBuildingElementProxy zur Definition von BRI/BGF.	Jeder Raum als IfcSpace zur Definition der NRF und der UGF gem. ÖN B1800 / SIA416 bzw. d0165. Geschossweise getrenntes Gebäudevolumen als IfcBuildingElementProxy zur Definition von BRI/BGF.	Jeder Raum als IfcSpace zur Definition der NRF und der UGF gem. ÖN B1800 / SIA416 bzw. d0165. Geschossweise getrenntes Gebäudevolumen als IfcBuildingElementProxy zur Definition von BRI/BGF.	Jeder Raum als IfcSpace zur Definition der NRF und der UGF gem. ÖN B1800 / SIA416 bzw. d0165. Geschossweise getrenntes Gebäudevolumen als IfcBuildingElementProxy zur Definition von BRI/BGF.	Jeder Raum als IfcSpace zur Definition der NRF und der UGF gem. ÖN B1800 / SIA416 bzw. d0165. Geschossweise getrenntes Gebäudevolumen als IfcBuildingElementProxy zur Definition von BRI/BGF.
Komplexität Vertikale Bauelemente	nicht relevant.	Tragende/nichttragende Wände einschichtig modelliert.	Tragende/nichttragende Wände mehrschichtig modelliert, inkl. aller relevanter Schichten ab 1cm, in Abstimmung mit PH/TWP.	Tragende/nichttragende Wände mehrschichtig modelliert, inkl. aller relevanter Schichten ab 1cm, in Abstimmung mit PH/TWP.	Tragende/nichttragende Wände mehrschichtig modelliert, inkl. aller relevanter Schichten ab 1cm, in Abstimmung mit PH/TWP.	Tragende/nichttragende Wände mehrschichtig modelliert, inkl. aller relevanter Schichten ab 1cm, in Abstimmung mit AF.
Komplexität Horizontale Bauelemente	nicht relevant.	Tragende Decken inkl. Bekleidungen einschichtig modelliert.	Rohdecke sep. modelliert. Bekleidungen (FBA/AGD/UD) raumspezifisch/mehrschichtig modelliert, inkl. aller relevanter Schichten ab 1cm, in Abstimmung mit PH/TWP.	Rohdecke sep. modelliert. Bekleidungen (FBA/AGD/UD) raumspezifisch/mehrschichtig modelliert, inkl. aller relevanter Schichten ab 1cm, in Abstimmung mit PH/TWP.	Rohdecke sep. modelliert. Bekleidungen (FBA/AGD/UD) raumspezifisch/mehrschichtig modelliert, inkl. aller relevanter Schichten ab 1cm, in Abstimmung mit PH/TWP.	Rohdecke sep. modelliert. Bekleidungen (FBA/AGD/UD) raumspezifisch/mehrschichtig modelliert, inkl. aller relevanter Schichten ab 1cm, in Abstimmung mit AF.
Sonstige Bauelemente	nicht relevant.	Tragende Stützen/Träger modelliert.	Tragende/nichttragende Stützen/Träger inkl. Bekleidungen modelliert. Brüstungen/Geländer mit Basisgeometrie modelliert.	Tragende/nichttragende Stützen/Träger inkl. Bekleidungen modelliert. Brüstungen/Geländer mit Handlauf modelliert, Sonderbauteile deklariert.	Tragende/nichttragende Stützen/Träger inkl. aller relevanter Schichten ab 1 cm modelliert. Brüstungen/Geländer mit Handlauf modelliert, Sonderbauteile deklariert.	Tragende/nichttragende Stützen/Träger inkl. aller relevanter Schichten ab 1 cm modelliert. Brüstungen/Geländer mit Handlauf modelliert, Sonderbauteile deklariert.
Treppen/ Rampen	nicht relevant.	Treppen/Rampen mit Basisgeometrie einschichtig modelliert.	Treppen/Rampen mit Basisgeometrie inkl. Bekleidungen modelliert.	Treppen/Rampen mit Basisgeometrie inkl. Bekleidungen modelliert.	Treppen/Rampen inkl. aller relevanter Schichten ab 1 cm modelliert inkl. Entkoppelung.	Treppen/Rampen inkl. aller relevanter Schichten ab 1 cm modelliert inkl. Entkoppelung.
Erschliessungs-Elemente (bspw. Aufzugsanlage/ Rolltreppe)	nicht relevant.	Als schematisches Objekt	Als schematisches Objekt	Als schematisches Objekt	Als ausformuliertes Objekt	Als Hersteller-Objekt.

For each domain, there is a description for the respective LOG class and element type and how this element type must be geometrically formulated in the model (modeling specification).

The following example from the EIR of buildingSMART Austria describes the requirements for LOI classes 100 through 400 (in German):

LOI-Klassen AR-Modell

Wand (Beispiel)

Folgende Tabelle beschreibt die benötigten Merkmale der Elementklasse Wand (IfcWall[22]) in Abhängigkeit der LOI-Klasse. Der PredefinedType[23] ist verpflichtend zu deklarieren. Das Pset_WallSpecific muss in der BIM-Applikation angelegt werden. Es enthält Merkmale die zusätzlich zur buildingSMART-Struktur angegeben werden.

Phasenbezug

LOI-Klasse	MERKMALE ÜBERSETZUNG DE	MERKMAL-NAMEN	EINHEITENTYP	EINHEIT	VERORTUNG	VERANTWORTUNG
LOI100	Aussenbauteil	IsExternal	Wahrheitswert	TRUE/FALSE	Pset_WallCommon	AR
	RaumhoheWand	ExtendToStructure	Wahrheitswert	TRUE/FALSE	Pset_WallCommon	AR
	Status	Status	Text (Optionen-Set[24])	-	Pset_WallCommon	AR
	TragendesElement	LoadBearing	Wahrheitswert	TRUE/FALSE	Pset_WallCommon	AR/TWP
LOI200	BrandabschnittsdefinierendesBauelement	Compartmentation	Wahrheitswert	TRUE/FALSE	Pset_WallCommon	BS
	BrennbaresMaterial	Combustible	Wahrheitswert	TRUE/FALSE	Pset_WallCommon	BS
	Feuerwiderstandsklasse	FireRating	Text (Optionen-Set[24])	-	Pset_WallCommon	BS
	UWert	ThermalTransmittance	Wärmedurchgangskoeffizient	positive Zahl [W/m²K]	Pset_WallCommon	PH
LOI300	Brandverhalten	SurfaceSpreadOfFlame	Text (Beispiel [25])	-	Pset_WallCommon	BS
	Schallschutzklasse	AcousticRating	Text (Beispiel [26])	-	Pset_WallCommon	PH
LOI400	Ausfuehrung	ConstructionMethod	Text (Optionen-Set[24])	-	Pset_ConcreteElementGeneral	AR/TWP
	Betonart	TypeOfConcrete	Text	-	Pset_WallSpecific	AR/TWP
	BewehrungsgradFlaeche	ReinforcementAreaRatio	Bewehrungsgrad	positive Zahl [kg/m²]	Pset_ConcreteElementGeneral	AR/TWP
LOI500	- Noch zu definieren. -					

Tabelle 80: LOI-Klassen Elementklasse Wand

Chapter 3 – In-depth knowledge

3.6 LOIN and levels of detail (LOG, LOI)

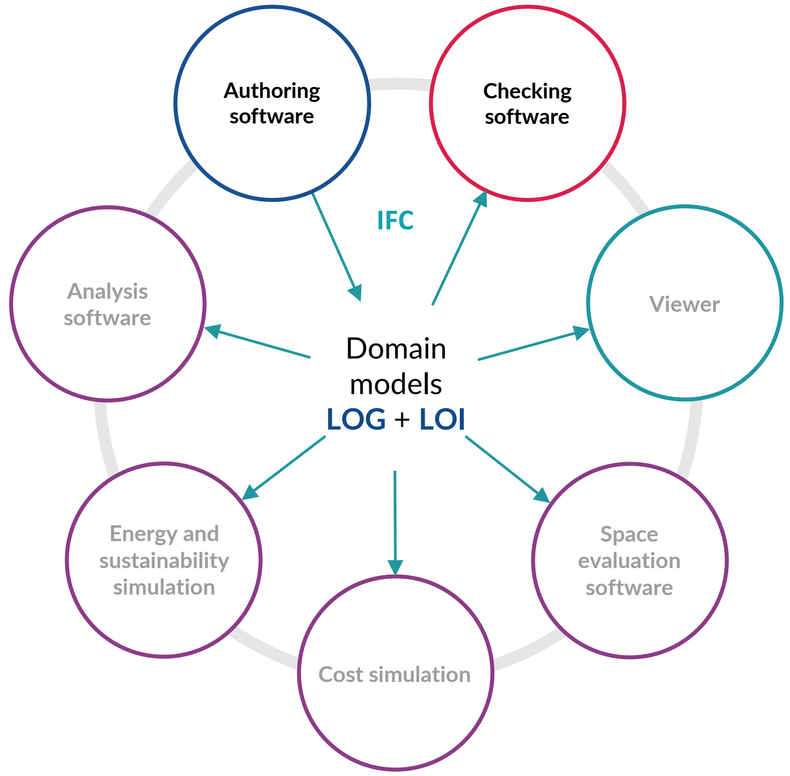
For each element class (entity), there is a set of *alphanumeric requirements* (= characteristics) for the respective LOI class, which an entity must completely contain at the end of the phase. In addition to the standard data contents of the IFC data structure (specific Pset contents), the specific characteristic requirements are also defined here.

The LOG and LOI levels of detail thus contain the *geometric* and *alphanumeric* content requirements for the domain models for data exchange and further use of the model data. The requirements are adopted in the respective authoring software and implemented in the model data = creation of model content. Both LOG and LOI serve as an important basis for the quality assurance of the *BGK* and *BFK* teams. They form the basic framework on which the checking content in the checking software is based, depending on the phase. The following checking routines are executed:

- **FCC** – formal criteria check
- **QCC** – quality criteria check
- **ICC** – integrity criteria check

They access the information in the LOG and LOI.

Further use of the model contents in other software (e.g., space layout program, evaluation program, etc.) is only possible using *checked* domain models *approved* by the *BGK*. Further use also takes place with the help of the contents of the LOG and LOI:



3.7 IDS – Information Delivery Specification

Guest authors: Léon van Berlo, Simon Fischer

IDS is a standard from buildingSMART International for the definition of computer-interpretable model exchange requirements. IDS is a relatively new standard and is complementary to MVD. While MVD deals with fundamental issues such as the correct representation of the class hierarchy and the geometry, IDS specifies the alphanumeric information of models. It defines the information requirements for objects. For this reason, IDS is a promising tool for providing and verifying client's information requirements defined in the EIR. It integrates the information requirements that currently exist as text into the automated openBIM process. IDS can be used for two sub-processes:

- Define information: As a configuration file for BIM authoring software, for the automated provision of the required information structure, and
- check information: As a configuration file for BIM checking software, for automated checking of the structure and content of the information.

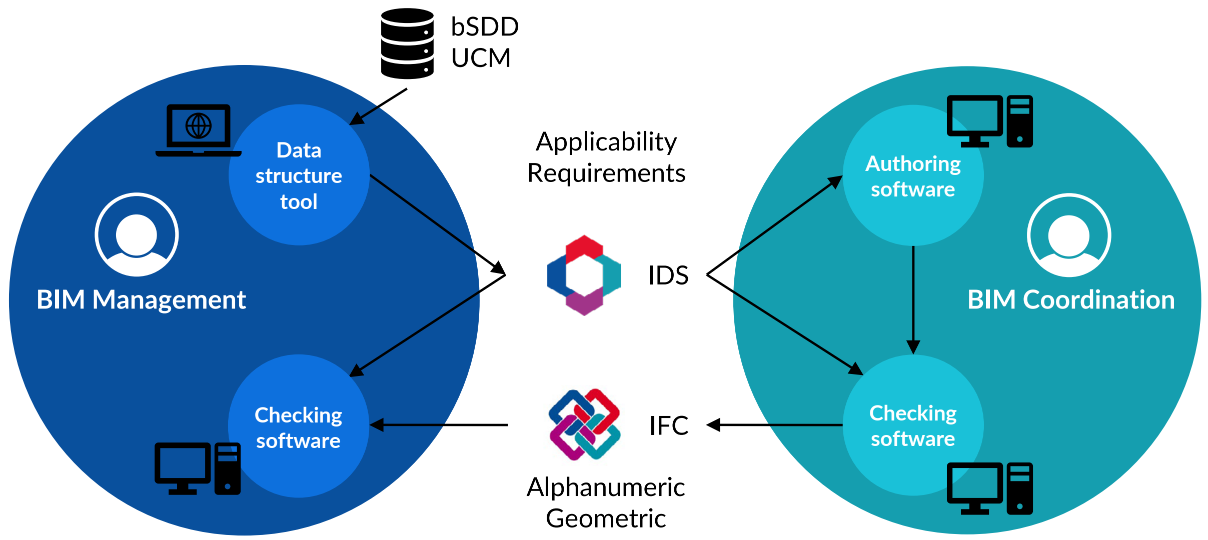
The IDS workflow starts with the client's area of responsibility (BIM management). The BIM management defines the desired BIM use cases and the required information. Let's look at two examples of information requirements.

First, a client might want all spaces in a model to be classified with a certain code, and have a couple of properties. The requirement could be described as »*All space data in a model shall be classified as [AT]Zimmer and have NetFloorArea and GrossFloorArea (both in set called BaseQuanitites) and a property called AT_Zimmernummer in the property set Austria_example.*« This is only an example. It could be any kind of requirement. Users can further refine requirements to not apply to all spaces but only to those with certain characteristics. For example, spaces with a certain property and/or property value, or spaces that are part of a certain hierarchy, or spaces that are classified in a certain way. This applies to all objects, not only spaces. The requirements for classification codes, materials, quantities, attributes, properties, materials and some relations can also be set for the selection (sometimes also called filtering; formally called applicability in IDS) of objects.

The applicability is included in the second example, a specification of certain properties for walls: »*All walls shall have the properties LoadBearing and FireRating (both in a property set called Pset_WallCommon). Walls with the value true for the property LoadBearing need a value for the property FireRating from the following list (ND, REI 30, REI 60, REI 90, REI 120).*« The space example is used later to show different ways of visualising IDS. The wall example is included in the description of the data structure of IDS in the next section.

The definition of information requirements is usually done using a data structure tool and taking into account data from the bSDD and the UCM. The BIM management then exports the information requirements in IDS and sends them to the contractor's BIM coordination or BIM creation. They use IDS as a configuration file for both the BIM authoring software and the BIM checking software.

This enables the authoring software to create the required properties on an object-specific basis automatically. In the BIM checking software, the configuration file enables automatic selection and filling of checking rules. The checked IFC file is finally sent to the BIM management, which also uses the IDS file to configure its checking software. In this way, IDS couples the client's information requirements with the BIM model and enables an automated checking of the defined information structure.



3.7.1 Data structure

The IDS file format is based on the XML scheme. It is a standardised form of it. This means that the structure and syntax of an IDS file are more precisely specified than those for a general XML file. For this purpose, buildingSMART International uses the XSD format (XML Schema Definition). This defines which elements must and may be included in an IDS file.

In principle, an IDS file is divided into two sections: a *Header* and a *list of Specifications*. The *Header* contains general metadata about the file. This is collected within the info element. Possible information in it are title, copyright, version, description, author, date, purpose, and milestone. Only the title is mandatory. All other parameters are optional. The lines before the metadata are the XML prolog for the definition of the XML version and the encoding, as well as the Root element (<ids ...>) with the definition of namespaces for the document.

```
<?xml version="1.0" encoding="UTF-8"?>
<ids xmlns="http://standards.buildingsmart.org/IDS" xmlns:xsi="http://www.w3.org/
2001/XMLSchema-instance" xsi:schemaLocation="http://standards.buildingsmart.org/
IDS/ids_09.xsd">
  <info>
    <title>IDS for BIMcert</title>
    <copyright>Simon Fischer</copyright>
    <description>Created to describe IDS for BIMcert</description>
    <date>2023-01-11</date>
  </info>
```

The general metadata is followed by the actual content of an IDS file: a list of *Specifications*. *Specifications* describe the information requirements for elements in IFC. A *Specification* consists of three parts: *Metadata*, *Applicability*, and *Requirements*.

The **Metadata** is included as XML attributes in the *Specification element*. In the following example, the two mandatory parameters, name and ifcVersion, are included. In addition, the necessity (occurs), an identifier, a description, and instructions can be defined. The description and instructions are options to add human-readable documentation to the requirements. While IDS is designed to be interpreted by computers, in many cases humans will inevitably need to add information to the BIM dataset. The creator of an IDS can therefore leave instructions that clarify any requirements for a human also to input data. The second component of the *Specification* is the **Applicability**. This filter defines for which elements the current *Specification* is applicable. This restriction can be carried out at the level of IFC classes but also much more specifically via *predefined types*, *properties*, *materials*, etc. The third component of the *Specification* are the **Requirements**. These contain the actual information requirements for objects. The combination of *Applicability* and *Requirements* creates the computer-interpretable definition of information requirements. Both components use so-called *Facets* to specify their content. In the context of XML, *Facets* mean restrictions for XML elements. In the IDS scheme, *Facets* describe information that an element in the IFC model might have. Six precisely defined *Facet* Parameters are used to make the requirements computer-interpretable. The *Facet* Parameters refer to different contents of the IFC scheme:

- *Entity Facet*
- *Attribute Facet*
- *Classification Facet*
- *Property Facet*
- *Material Facet*
- *PartOf Facet*

In the *Applicability*, the *Facets* enable very specific filter options (e.g., only elements that have a certain *property* with a certain value). It is also possible to combine several *Facets*, which increases the possibilities for defining individual requirements.

Through all of this functionality, IDS can provide advanced definitions of requirements. It allows users to require properties to be shared with a certain kind of measure. There are also extensive possibilities to define restrictions on values as well. For example, the value of a property can only be selected from a list of allowed values. Or if the value is a number, it can have a specified minimum, maximum or range. Even pattern matching is an option available in IDS. IDS uses the XSD restrictions for this to improve the reliability of the implementation. Restrictions on specifications are another example of an advanced feature. The *minOccurs* and *maxOccurs* XML attributes allow users to define a minimum, maximum, range, or the exact number of objects that must be present in the BIM dataset. The *PartOf facet* allows users to require certain structures in the BIM dataset that are typical when using IFC. *Requirements* for an object to be part of an assembly or part of a group can be defined using this functionality. Details on the different facet parameters follow in a later section.

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3.7 IDS – Information Delivery Specification

In the following, the example of information requirements for walls from the introduction is shown both in normal text in tabular form (common in several countries) and in IDS. The first *Specification* states that each wall requires the *properties* LoadBearing and FireRating in the *property set* Pset_WallCommon. The second *Specification* provides possible values for the fire resistance class of load-bearing walls (the list is not comprehensive). The *Applicability* of both specifications is highlighted in light blue, the *Requirements* in light orange.

LOI – Level of Information (IfcWall)

Property	Data type	Unit of value	Location	Selection set	Note
LoadBearing	IfcBoolean	Logical value	Pset_WallCommon	-	Default value: FALSE
FireRating	IfcLabel	Text	Pset_WallCommon	Selection set	Default value: ND; Example: REI 60
...					

Selection sets IfcWall FireRating

load bearing	non-bearing	...
ND	ND	
REI 30	EI 30	
REI 60	EI 60	
REI 90	EI 90	
REI120	EI120	
...	...	

```
<specifications>
  <specification name="IfcWall General" ifcVersion="IFC4">
  <applicability>
      <entity>
        <name>
          <simpleValue>IFCWALL</simpleValue>
        </name>
      </entity>
    </applicability>
    <requirements>
      <property measure="IfcBoolean">
        <propertySet>
          <simpleValue>Pset_WallCommon</simpleValue>
        </propertySet>
        <name>
          <simpleValue>LoadBearing</simpleValue>
        </name>
      </property>
      <!-- further properties -->
    </requirements>
  </specification>
```

```
  <specification name="IfcWall FireRating for LoadBearing walls" ifcVersion="IFC4">
    <applicability>
      <entity>
        <name>
          <simpleValue>IFCWALL</simpleValue>
        </name>
      </entity>
      <property measure="IfcBoolean">
        <propertySet>
          <simpleValue>Pset_WallCommon</simpleValue>
        </propertySet>
        <name>
          <simpleValue>LoadBearing</simpleValue>
        </name>
        <value>
          <simpleValue>true</simpleValue>
        </value>
      </property>
    </applicability>
    <requirements>
      <property measure="IfcLabel">
        <propertySet>
          <simpleValue>Pset_WallCommon</simpleValue>
        </propertySet>
          <name>
            <simpleValue>FireRating</simpleValue>
          </name>
          <value>
            <xs:restriction base="xs:string">
              <xs:enumeration value="ND"/>
              <xs:enumeration value="REI 30"/>
              <xs:enumeration value="REI 60"/>
              <xs:enumeration value="REI 90"/>
              <xs:enumeration value="REI 120"/>
            </xs:restriction>
          </value>
        </property>
      </requirements>
    </specification>
  </specifications>
</ids>
```

3.7.2 Relation to the buildingSMART Data Dictionary

When a user receives an IDS from a client, they can check their own data against the requirements defined in the IDS. As mentioned earlier, the IDS can include human-readable explanations and instructions to help the receiving human understand the requirements. It is also possible in IDS to add a link (formally called a *Uniform Resource Identifier*, URI) with more information about a property or

classification code. This is where the relation to the buildingSMART Data Dictionary (bSDD) comes into the picture. A URI starting with *identifier.buildingsmart.org* refers to an object that can be found in the bSDD. By following this URI, the user can obtain more information about a property beyond the level of detail that can be specified within the IFC. The bSDD hosts detailed, standardised information about definitions, units, relations to other objects, etc. It does this for classification codes, properties (including attributes and quantities) and materials, for both international and national-specific standards. The options for defining restrictions on values in IDS are the same as those supported by bSDD. This allows seamless interaction between IDS and bSDD. Adding the URI to a property or classification code (or system) allows users, and in some cases, even computers, to gather more information about the requirement and the typical use of objects. More information about the bSDD can be found in the dedicated bSDD section of this book.

3.7.3 Facet parameters

This section covers the functionality and capabilities of the six *Facet Parameters*. For *Facets*, as for *Specifications*, the necessity (occurs) can be specified as an XML attribute. Some *Facets* also offer other specific XML attributes. The following description contains a sample code for each *Facet*. The first two samples are each included in the *Applicability* of a *Specification*. The others can be included in the same way in the *Applicability* or the *Requirements* of any *Specification*.

Entity Facet

The *Entity Facet* refers to the classes in the IFC scheme. It is, therefore, particularly important for defining the *Applicability*, as it describes for which IFC class a *Specification* is relevant. In addition to the mandatory name of the IFC class, a *predefinedType* of an element can optionally be specified in the *Entity Facet*. The following code snippet shows the use of the *Entity Facet* to define the *Applicability* of a *Specification* to all elements of the IFC class IfcDoor.

```
<applicability>
  <entity>
    <name>
      <simpleValue>IFCDOOR</simpleValue>
    </name>
  </entity>
</applicability>
```

Attribute Facet

The *Attribute Facet* deals with attributes that are included by default in IFC classes. Examples are the name of an element or the GUID. To use the facet, the name of the attribute must be specified. The value of the attribute is optional. If only a name is defined, the element must have an attribute with the specified name and any defined (non-empty) value. The following code snippet illustrates the use of the *Attribute Facet* to define the *Applicability* of a *Specification* to all elements of the IFC class IfcDoor with the name Entry.

```
<applicability>
  <entity>
    <name>
      <simpleValue>IFCDOOR</simpleValue>
    </name>
  </entity>
  <attribute minOccurs="1" maxOccurs="1">
    <name>
      <simpleValue>Name</simpleValue>
    </name>
    <value>
      <simpleValue>Entry</simpleValue>
    </value>
  </attribute>
</applicability>
```

Classification Facet
If other classification systems are used in addition to the classes of the IFC scheme, these can be taken into account with the *Classification Facet*. Examples of such external classification systems are Uniclass2015 or national systems. The *Classification Facet* allows the specification of a classification system and a reference code (how an object is classified within the system). Both parameters are optional. If no parameter is specified, an object must be classified in any system with any reference code. In addition, a URI can be added as an XML attribute of the Classification Element to link to further information. In this example, the system Uniclass2015 with an arbitrary reference code is required.

```
<classification minOccurs="1" maxOccurs="1">
  <system>
    <simpleValue>Uniclass2015</simpleValue>
  </system>
</classification>
```

Property Facet
The *Property Facet* is the counterpart to the *Attribute Facet* and refers to the *properties*. In addition, it can also be used to specify quantities. To define a requirement, the parameters *propertySet* (*quantitySet*), *property name* (*quantity name*), value, and data type (measure) are used. The value of the *property* is optional, like in the *Attribute Facet*. All other parameters are mandatory but note that the data type has to be specified as an XML attribute of the *Property Element*, not as an individual XML element like the others. A URI can also be added as an XML attribute to link, e.g., to the bSDD. The example *Specification* given here requires a property LoadBearing with the value true and the data type IfcBoolean in the *property set* Pset_WallCommon.

```
<property measure="IfcBoolean" minOccurs="1" maxOccurs="1">
  <propertySet>
    <simpleValue>Pset_WallCommon</simpleValue>
  </propertySet>
```



```
  <name>
    <simpleValue>LoadBearing</simpleValue>
  </name>
  <value>
    <simpleValue>true</simpleValue>
  <value>
</property>
```

Material Facet
When using restrictions regarding materials, remember that an object can consist of one or more materials. The *Material Facet* checks whether one of the materials of the corresponding object matches the specified material. There is only one optional parameter for the material within this *Facet*. If not defined, any material specification must be present. A URI can be used as an XML attribute of the Material Element to link to additional information about the material.

```
<material minOccurs="1" maxOccurs="1">
  <value>
    <simpleValue> ExampleMaterial</simpleValue>
  </value>
</material>
```

PartOf Facet
The *PartOf facet* can be used to specify *Relations* between objects. Relations are defined in IFC via classes starting with IfcRel.... In the *PartOf Facet*, a *Relation* can be specified via such a relation class and the IFC class to which the *Relation* refers. Note that the *Relation* is specified as an XML attribute of the *PartOf element*, not as an individual XML element like the others. The following code snippet shows a requirement that an element must be assigned to a floor. For this purpose, the Relation IfcRelContainedInSpatialStructure and the class IfcBuildingStorey are specified.

```
<partOf relation="IfcRelContainedInSpatialStructure" minOccurs="1" maxOccurs="1">
  <entity>
    <name>
      <simpleValue>IFCBUILDINGSTOREY</simpleValue>
    </name>
  </entity>
</partOf>
```

3.7.4 Simple Values and complex restrictions
In addition to the possibility of specifying requirements for different contents of the IFC scheme via the *Facets*, the requirements themselves can also be defined in different ways. For this purpose, IDS first distinguishes between Simple Values and Complex Restrictions. Simple Values are single values in the form of a text, a number or a logical value (true/false). Complex Restrictions allow the specification of several values and can be divided into four subcategories:

Enumeration
The Enumeration is used to specify a list of allowed values. The list can contain both text and numbers. Below is an example of specifying fire resistance classes for load-bearing walls (the list is not comprehensive).

```
<value>
  <xs:restriction base="xs:string">
    <xs:enumeration value="ND"/>
    <xs:enumeration value="REI 30"/>
    <xs:enumeration value="REI 60"/>
    <xs:enumeration value="REI 90"/>
    <xs:enumeration value="REI 120"/>
  </xs:restriction>
</value>
```

Pattern
A *Pattern* describes the order in which different characters may be arranged. This functionality is mainly applicable to naming conventions or naming schemes. A widespread method for defining such patterns, which is also used for IDS, are *Regular Expressions* (*Regex*). The following code snippet shows an example of a room naming convention. `[A-Z]` means the name begins with a capital letter. `[0-9]{2}` specifies that it is followed by two digits between 0 and 9. `–[0-9]{2}` states that the name has to end with a hyphen and two digits between 0 and 9. Valid names are, e.g., W01-01 or B18-74.

```
<value>
  <xs:restriction base="xs:string">
    <xs:pattern value="[A-Z][0-9]{2} -[0-9]{2}"/>
  </xs:restriction>
</value>
```

Bounds
Bounds define an interval of valid values. It is possible to specify either a lower limit, an upper limit, or both. The limits can also be defined as exclusive </> or inclusive <=/>=.

Length
Finally, it is possible to specify the length of a value, i.e., the number of individual characters. You can specify an exact length as well as a minimum or maximum length.

3.7.5 Scope and use of IDS

An IDS file can contain multiple requirements. These requirements are independent »blocks« and have no reference to other requirements in the file. This is intentionally done to create the ability to copy-paste requirements between files. At the time of writing, several software vendors are implementing IDS editors and authoring tools to facilitate users with an easy way to create IDS files. In the future, buildingSMART envisages the existence of IDS libraries where examples of individual requirements are shared for everyone to use. Users will be able to search for IDS requirements and drag them into a selection basket to create their own IDS file. An important scope definition of IDS is that it focuses only on »information delivery specifications«. This means that the IDS structured requirements can define what information is needed and how it should be structured. It is important for automated workflows and scripts to receive information in such a way that it can be processed automatically, and this is the aim of IDS. However, IDS cannot be used to define design requirements or so-called »*rules*«. So, a requirement that all windows in a toilet room need to have an opaque glass is not possible within IDS; but a requirement that all windows need to have a property that defines what type of glass is in the window is a perfect definition to define in IDS. A rule checker or other algorithm should then be used to check whether windows in toilet rooms have an opaque glass or not. There is a grey area on this since IDS allows restrictions of values. Future releases of IDS will further refine this scope or extend the ability of IDS to define rules. Practical use cases and consensus will define the future possibilities of IDS.

3.7.6 New possibilities with IDS

In addition to the integration of information requirements into the automated openBIM process, IDS also offers new possibilities for the specific definition of these requirements by the *Applicability*. Typically, EIR define information requirements based on IFC classes and *predefined types*. In contrast, IDS can define information requirements depending on all described *Facets*. For example, a certain *property* in a particular *property set* only becomes necessary when another *property* in another *property set* has a certain value. This enables clients to request and check information very specifically.

3.7.7 IDS in depth

All technical information about IDS can be found on GitHub, where the code development, documentation, and examples are stored. The international community has identified IDS as the most advantageous method for automated compliance checking by validation of the alphanumerical information requirements. It supports information requirements authoring by providing users with a set of possibilities on what can be required of the models.

3.7.8 Relationship with other initiatives

There are many ways to define information requirements. Excel seems to be the most popular, but it has limitations. Other initiatives are the Product Data Templates (PDT), Level of Information Need (LOIN), Exchange (or Employer) Information Requirements, BIM Execution plans, the »*exchanges*« part of mvdXML, SHACL in the linked data domains, and more. All of these initiatives have advantages and limitations. Depending on the use case, other standards or initiatives may be a better choice. A comparison created by Tomczak et al. can be found here (see QR code).

○ – No
◑ – Partial
● – Yes
* – under development

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			Fields					Value constraints				Content			Geom.		Metadata		
	Standardised	Applicability	Info. type	Data type	Unit of meas.	Description	References	Equality	Range	Enumeration	Patterns	Existence	Documents	Structure	Representation	Detailedness	Purpose	Actors	Process map
Spreadsheet	○	◑	◑	◑	◑	◑	◑	◑	○	○	○	○	○	○	○	○	◑	○	○
PDT*	●	◑	◑	●	●	◑	●	○	◑	●	○	◑	○	○	○	○	◑	○	○
Data Dict.	●	○	●	●	◑	●	●	●	◑	●	◑	○	○	○	○	○	○	○	○
IDS*	●	●	●	●	●	◑	◑	●	●	●	●	●	○	◑	○	○	●	◑	○
mvdXML	●	●	●	●	●	◑	○	●	●	◑	◑	◑	○	●	●	○	○	◑	○
idmXML	●	◑	◑	◑	◑	●							●		◑	◑	●	●	●
LOIN*	●	◑	◑	●	●	◑	◑	○	○	●	○	○	●	◑	◑	●	●	●	○
IFC P.T.	●	◑	◑	●	●	◑	○	○	○	●	○	○	○	○	○	○	○	○	○
LD+SHACL	○	●	●	●	●	◑	●	●	●	●	●	◑	◑	●	●	○	◑	◑	○

For most use cases in openBIM, the IDS is the recommended solution for defining information requirements. It balances compatibility with IFC and bSDD with ease of use and reliability. Several software tools are available to check an IFC file against the requirements of an IDS file. Typically, the results are displayed in a viewer. To share the results, it is recommended to use the BIM Collaboration Format (BCF). BCF is a structured way of sharing information about IFC objects with project partners. For more information on BCF, see another section in this book.

3.7.9 Different ways to visualise IDS

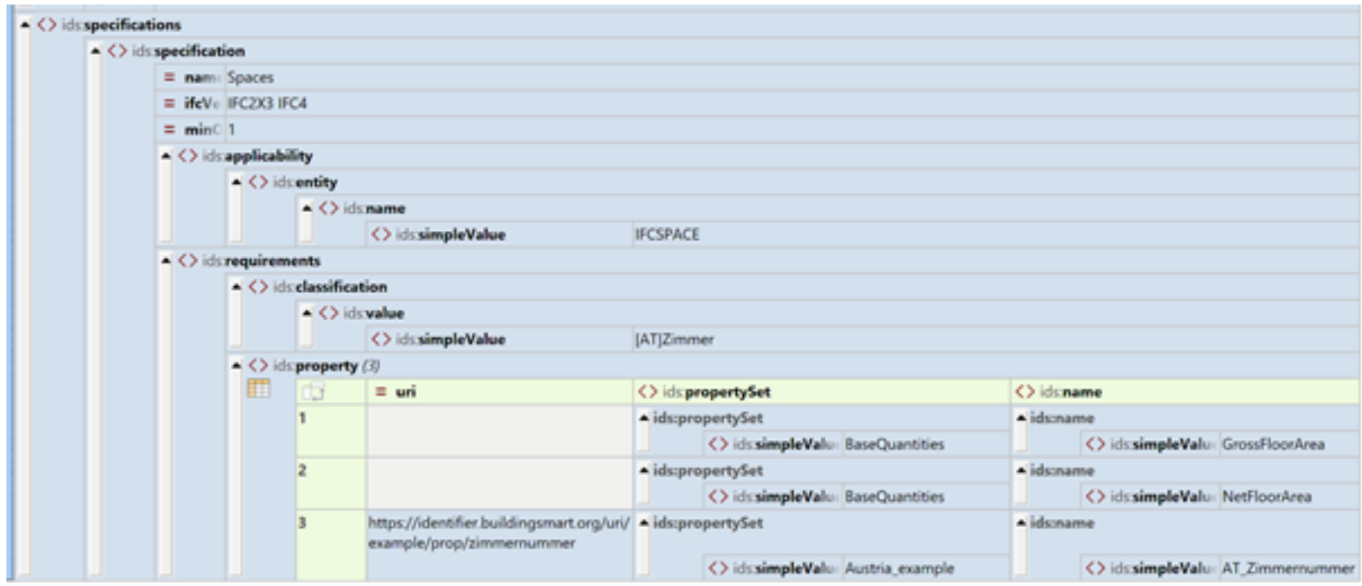
In this section, the information requirement example for spaces from the introduction is used to show different ways how to visualise IDS. The requirement states: »*All space data in a model shall be classified as [AT]Zimmer and have NetFloorArea and GrossFloorArea (both in set called BaseQuanitites) and a property called AT_Zimmernummer in the property set Austria_example.*« Formatting this human-readable requirement in an IDS looks like this:

```
<ids:ids xmlns:xs="https://www.w3.org/2001/XMLSchema" xmlns:ids=" http://
standards.buildingsmart.org/IDS">
  <ids:info>
    <ids:title>Austia example</ids:title>
    <ids:copyright>buildingSMART</ids:copyright>
    <ids:version>0.0.3</ids:version>
    <ids:description>A few example checks</ids:description>
    <ids:author>contact@buildingsmart.org</ids:author>
    <ids:date>2023-01-16+01:00</ids:date>
  </ids:info>
```



```
  <ids:specifications>
    <ids:specification minOccurs="1" ifcVersion="IFC2X3 IFC4" name="Spaces">
      <ids:applicability>
        <ids:entity>
          <ids:name>
            <ids:simpleValue>IFCSPACE</ids:simpleValue>
          </ids:name>
        </ids:entity>
      </ids:applicability>
      <ids:requirements>
        <ids:classification>
          <ids:value>
            <ids:simpleValue>[AT]Zimmer</ids:simpleValue>
          </ids:value>
        </ids:classification>
        <ids:property>
          <ids:propertySet>
            <ids:simpleValue>BaseQuantities</ids:simpleValue>
          </ids:propertySet>
          <ids:name>
            <ids:simpleValue>GrossFloorArea</ids:simpleValue>
          </ids:name>
        </ids:property>
        <ids:property>
          <ids:propertySet>
            <ids:simpleValue>BaseQuantities</ids:simpleValue>
          </ids:propertySet>
          <ids:name>
            <ids:simpleValue>NetFloorArea</ids:simpleValue>
          </ids:name>
        </ids:property>
        <ids:property url="https://identifier.buildingsmart.org/url/example/prop/
zimmernummer">
          <ids:propertySet>
            <ids:simpleValue>Austria_example</ids:simpleValue>
          </ids:propertySet>
          <ids:name>
            <ids:simpleValue>AT_Zimmernummer</ids:simpleValue>
          </ids:name>
        </ids:property>
      </ids:requirements>
    </ids:specification>
  </ids:specifications>
</ids:ids>
```

A different way to visualise this XML is shown in the figure. Here you can see the same information but structured as a table. This is a very generic view that can be applied to all XML files.



There are also specific viewers that read the XML-based IDS and visualise it in a human-readable way. In such a viewer, our example looks like this. As you can see, there are many different ways to visualise the information in an IDS file.

Austria example

contact@buildingsmart.org 0.0.3 2023-01-16+01:00 Construction

A few example checks

© buildingSMART

Spaces

Describe why the requirement is important to the project.

Provide instructions on who is responsible and how to achieve it.

APPLIES TO:

All *Space* data

REQUIREMENTS:

Shall be classified as *[AT]Zimmer*
Gross Floor Area data shall be provided in the dataset *BaseQuantities*
Net Floor Area data shall be provided in the dataset *BaseQuantities*
A T_ Zimmernummer data shall be provided in the dataset *Austria_example*

3.7.10 Relationship IDS to IFC

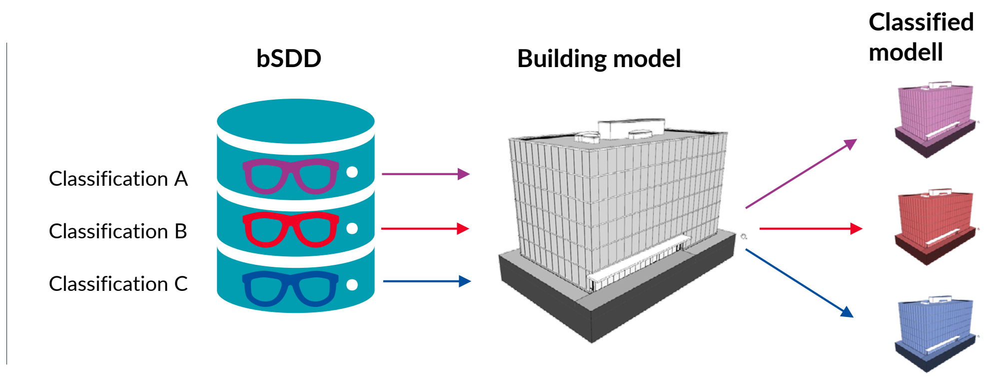
Although IDS can be used to request any type of data in the build asset industry, it works best on data that is structured according to the IFC standard. As you see in the space requirement example (in the line *specification*), this specification requires there to be at least one object like this in the model. It also states that this requirement is made for both IFC2x3 and IFC4. The applicability part of this IDS also states IFCSPACE. This is an IFC entity. So although the specification can be used for non-IFC data, the IDS tends to prefer specifications that are made on IFC. This can also be seen in the split between attributes and properties, and the *PartOf* relationships in advanced requirements.

3.8 bSDD – buildingSMART Data Dictionary

Guest authors: Jan Morten Loës, Frédéric Grand

Creating a complex building model is time-consuming and requires a great deal of coordination and agreement. The manual or automated creation of the relevant elements must be accurate and at the required level of detail. However, geometry is only one part of the BIM model. An important part is the alphanumeric data that the model can carry, i.e., the characteristics of each element. The IFC standard provides a reasonable basis, but with markets and products growing and changing daily, it is impossible to include every relevant feature in an international standard. In addition, there is the need to meet the many regionally varying requirements of laws and regulations imposed on a building. Compliance with these requirements must be demonstrated by appropriate information in the model. This information can be provided by extending the IFC standard or by linking to appropriate sources outside the model. This gives the IFC standard the flexibility to cover most conceivable cases of data requirements. The bSDD has been introduced by buildingSMART for this purpose.

Contrary to its name, the bSDD is not just a dictionary but a *data structure* server. On the one hand, it enables any institution to create its own data structures, publish them, and link them to existing data structures. On the other hand, individual users can access these structures to enrich their own models with data or to view them from a different perspective (a different classification). In this way, the same model can be used for several calculations, assessments, and simulations without changing the model's geometry or structure. It is sufficient to connect the existing elements through a classification with the corresponding data structure on the bSDD to move from one view to the next (see figure: bSDD as a classification server). For example, the use of different materials or products can be checked and simulated in the model to determine the optimal performance in terms of environmental assessment, energy consumption, fire safety, or cost.



Communication with the bSDD is via APIs. Software solutions have been developed both for the input of data by providers and for the use of data in the model. buildingSMART deliberately does not provide its own user interface to encourage the development and competition of needs-based solutions in the market. Therefore, buildingSMART only provides a simple graphical user interface.

3.8.1 Aim and benefit

The bSDD aims to provide a centralised data structure and feature server that allows worldwide access and minimises redundancy through the interconnectivity of content. The following objectives can be highlighted:

- Unify and consolidate classification systems,
- create a globally uniform address for finding and using classifications and declarations,
- reduce redundancies,
- create a basis for data consistency in digital processes in the construction and planning sector, and
- provide mapping functions to relate various classifications and declarations to each other.

This translates directly into added value for all users:

- The possibility to declare own domains, classifications, features, and structures, and to make them available worldwide in a binding way,
- linking your own classification systems with other existing domains,
- establish clear data structures, avoid misunderstandings,
- more efficient data management,
- offloading of information from the building model,
- enriching the own building model with external declarations and classifications as well as
- (further) use of already created structures.

3.8.2 Stakeholder

In principle, anyone is free to create their own domain. Approval must be obtained from buildingSMART, stating the purpose and benefit of the domain to be created and the person or institution responsible. However, the aim of the creation should never be to mirror existing classifications but to complement them with a broad consensus. The bSDD is free of charge and can be used by any person or institution thanks to its open interfaces. Due to its wide range of functions, the bSDD offers advantages for many users and applications. Therefore, the following list is not exhaustive:

- Clients can check and control the desired certification via data structures hosted on the bSDD.
- Planners can use the added information value of the bSDD to enhance their models.
- Service providers and web services can connect to the bSDD via the API and perform fully automated checks.
- Authorities can check submitted models against their own standards on the bSDD.
- Manufacturers can publish their product data templates to enable data consistency between planners, suppliers, contractors and operators.
- BIM project management and BIM project controlling can access the bSDD to check compliance with standards and project-related specifications.

3.8.3 Use cases

The wide range of functions and the open interfaces enable a variety of use cases in which the bSDD can play a (central) role (without claiming to be complete):

- product descriptions,
- creating IDS,
- enriching a model with features from a classification or an existing standard,
- verification of compliance with a standard,
- multilingual search, and
- Interchangeability of products.

Some examples of use cases are given below.

Use Case 1: Assigning classification codes to IFC elements in a BIM model
The bSDD provides the ability to map classification system codes to the corresponding IFC element classes, depending on the values of the characteristics assigned to the IFC element class. For example, suppose a client has requested the provision of Uniclass codes (UK National Building Specification (NBS) classification system) in the deliverables of a project. In that case, this can be easily achieved using the extended mapping provided by bSDD. In this case, the BIM authoring software used will apply the same process to all entities present in the digital model:

- Search for the bSDD classification entries associated with the IFC element class,
- if the classification entries have IFC feature settings:
  - check the feature values associated with the IFC element class and
  - select the classification code assigned to the IFC element class in the context of the values.

For example, a load-bearing exterior wall can have a class that requires both the LoadBearing and IsExterior features to be set to true to be considered an exterior wall in this classification.

Use Case 2: Verification of the classification code attached to IFC elements in a digital model
This use case is similar to Use Case 1. Instead of adding classification codes, the aim here is to check the classification codes already present in a digital model. Using the bSDD, it is possible to check whether the classification codes assigned to an IFC element class are valid according to the definition and mapping provided in the data dictionary.

Use Case 3: Enrichment of a digital model with specific local or technical properties.
The bSDD can carry the data structures of (construction/equipment) products and their associated characteristics as described in technical standards (e.g., harmonised European product standards). These are linked in the bSDD via relationships to the corresponding IFC element classes. Therefore, it is possible to follow the procedure described in Use Case 1 to add appropriate product-related technical properties to the digital model. For example, it is possible to

add specific fire safety properties according to a national fire safety regulation or properties required to create the EPD (Environmental Product Declaration) for a specific product to perform a Life Cycle Carbon Assessment.

Use Case 4: design2Certificate
A digital building model can be optimised through simulation even before construction. Different (construction/equipment) products can be anchored in the building model to perform the calculation on a realistic database (of generic or specific products). Suppose a common data structure or classification is used. In that case, it is possible to replace any product with another by providing the corresponding model elements with the respective deviating manufacturer's values by means of classification. Thus, without changing the structure of the model, building performance can be simulated and checked with different materials, and the optimised result can then be transferred to the model and made available for execution.

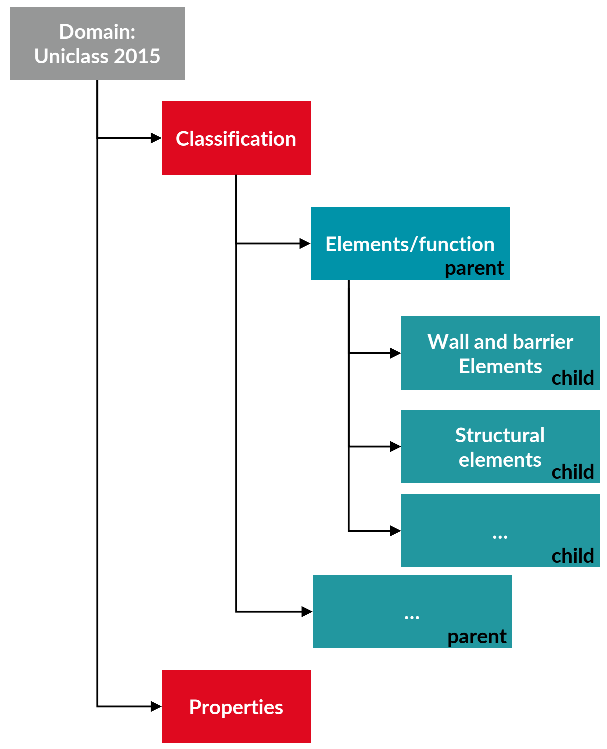
3.8.4 bSDD in detail

The full structure of bSDD is documented on GitHub (see QR code). Several concepts can be used to create the data structure of a domain. For example, the relationships provided allow the needs of taxonomy (parent-child relationship) and meronymy (part-whole relationship) to be met. bSDD provides a predefined list of relationship options, e.g., IsEqualTo, IsChild, IsParent, HasPart. Using these relationship specifications, various relationships can be created within and outside the domain. Each domain is free in the design of the structure, whether sub-classifications (child-parent relationship) exist and whether properties are required. For example, the following figure (top of the next page) shows the possibility of classifications with sub-classifications.

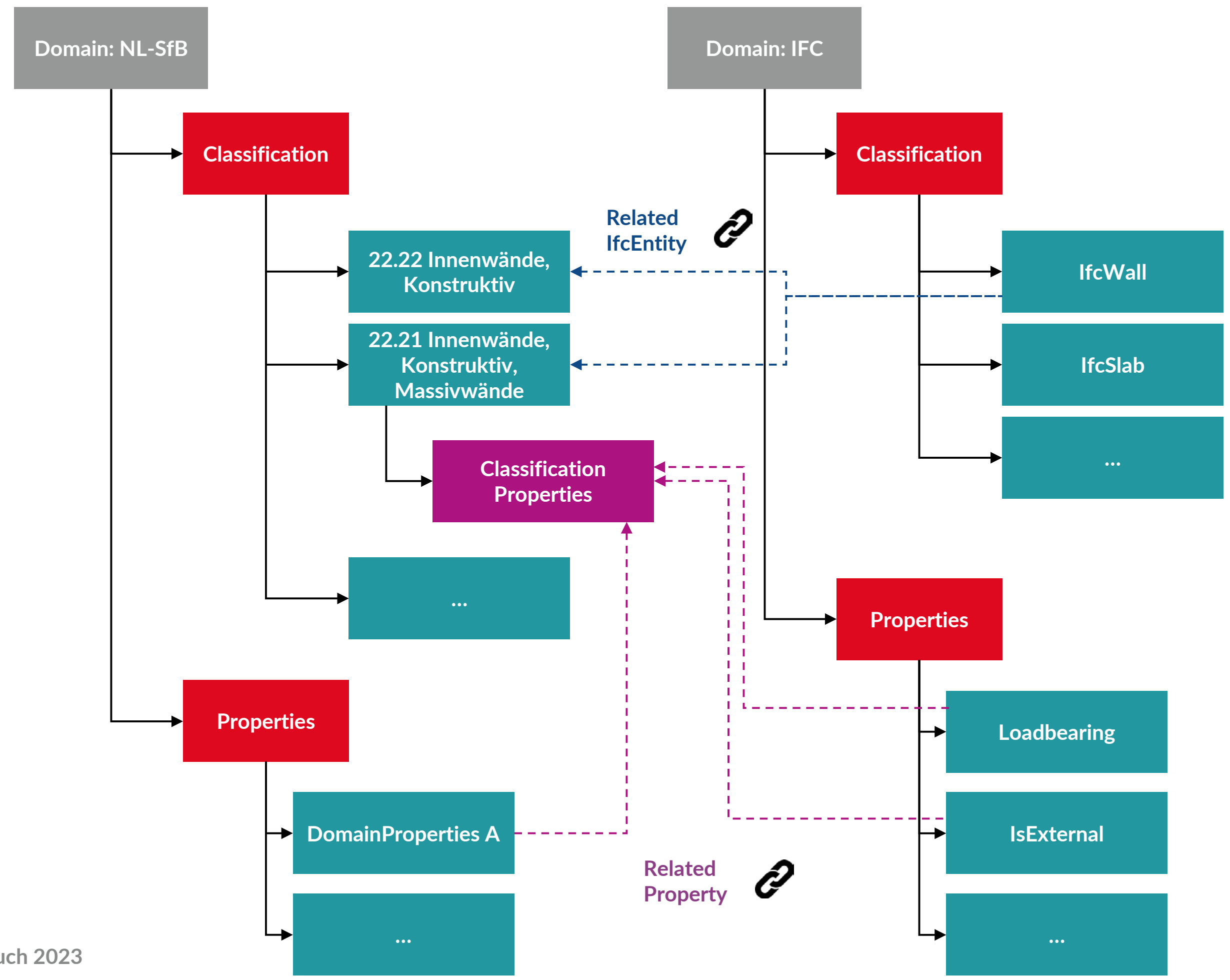
For each type of concept (classification, element classes, characteristics, units, reference documents, value ranges, relationships, linked elements, external links and multilingual equivalents, etc.), a complete definition is provided as well as a list of metadata that can be associated with the concept.

Hierarchy of a classification system
Typically, a classification system is described using a tree structure and then mapped in the context of IFC element classes. For example, the Uniclass Classification 2015, owned by NBS and released under *Creative Commons Attribution-NoDerivatives 4.0 International*, is modelled as shown in the figure below: All elements are represented in a tree structure (parent/child). The classification system for Uniclass does not include properties.

The second figure (bottom of next page) shows a domain without sub-classification, but the properties are linked to the classification.



Hinweis: Domain hat keine Property definiert



Mapping
Each element of the hierarchy can be mapped in the context of the corresponding IFC element class. The following figure shows that the hierarchy shown can be extended by adding a relationship between the classification codes of the *NL-SfB* domain and the corresponding IFC element classes in the *IFC* domain. A classification can also reuse properties from other domains to avoid duplication in the bSDD. In this example, the *NL-SfB* classification is represented by element classes. A link is made to some *IFC* domain properties to extend the definition of the classification codes. Here *NL-SfB* specifies that classification code 22.21 uses the LoadBearing and IsExternal features provided by the *IFC* domain rather than creating duplicate features in the NL-SfB domain.

Advanced mapping
Achieving a complete 1:1 mapping between a classification and IFC element classes is also possible. In this case, we can represent that a classification code corresponds to an IFC element class where some properties have predefined values. bSDD allows us to represent that a classification code corresponding to an internal load-bearing wall is identical to the IFC element class IfcWall only if the properties LoadBearing are set to true and IsExternal is set to false. This powerful mapping functionality is suitable for use cases where classification codes need to be automatically added to an IFC-based digital model or where the validity of classification codes present in the model needs to be checked.

3.8.5 Implementation

There are already several products that have integrated the bSDD into their software. These include the bSDD-connector with the usBIM browser from ACCA software and the Sketchup plug-in from DigiBase. The content is retrieved from the bSDD. In addition to the software mentioned, the bSDD can also be accessed via the search page already set up on the bSDD platform.

A developer or software can also access the bSDD via the REST API. The instructions are available on GitHub (see QR code).

As the standard API is very inflexible, the content of the bSDD can also be accessed using a query language: GraphQL. Further instructions and notes can be found in the buildingSMART documentation for the bSDD and GraphQL (see QR code).

3.9 UCM – buildingSMART Use Case Management Service

Guest author: Thomas Glättli

3.9.1 Basics

Information management and data-based collaboration

The prerequisite for consistent information management and data-based collaboration is a common understanding of the information required – both from the point of view of ordering and provision and use. The focus is on the information needs of the actors involved at predefined points in the process and the clear definition of information.

The EN ISO 19650 series of standards identifies the process and roles in providing information from the point of view of the information provider and the information requester. This standard defines the hierarchical structure and implementation of information requirements. The information requester defines the goals or requirements for the information that the information provider must provide from a defined point throughout the project. This enables business decisions based on a regulated flow of information.

EN 17412-1 provides the methodological basis for defining the Level of Information Need (LOIN). The methodology is based on two main steps. The first step defines the need (what for, when, who, what), and the second describes the depth of information (how).

BIM Use Cases

BIM use cases describe the purpose for which data and information are created and used in a digital building model. A use case describes the business case and the ideal scenario, including the objectives and success criteria for information exchange. Different parties and their responsibilities are defined as roles. At the same time, their activities in the information exchange are described. Agreements, contracts, standards, etc., concretise external conditions that affect the goals or results of the information exchange.

Each use case follows an overarching goal and focuses on a specific outcome or benefit. According to LOIN, a use case defines who provides what information to whom, at what time, in what format, and at what level of detail. A BIM project is specified by a large number of use cases. In this way, it is possible to define how the required information is made available to the relevant users in the required quality and at the correct stage throughout the modelling process.

Typical use cases describe the process of model-based quantity and cost calculations, the presentation of embodied energy and operational energy requirements, the planning of the construction process, the organisation of site logistics, and the provision of information for operations. A general description of such use cases forms the basis for the networked, collaborative and integrative design, construction and operation of a building. The following figure illustrates that use cases address the entire value chain.

Information Delivery Manual (IDM)

The primary control tool, the Use Case Definition, is based on international standards. The Use Case Management Service is based on these standards and provides users with a secure and standardised way of developing use cases.

The uniform description of use cases and the definition of exchange requirements are based on the ISO 29481 (IDM) series of standards. This standard defines the framework and methods for representing processes and exchanging requirements for a specific purpose. It also describes how to ensure that the information exchanged is correct and complete and that activities can be performed. An IDM facilitates interoperability between software applications and promotes digital collaboration between those involved in the construction process. It provides the basis for accurate, reliable, repeatable, and high-quality information exchange.

A use case is identical to an Information Delivery Manual (IDM). Both follow the same scheme and are classified in the same way. While a Use Case describes a single, specific use case that is as well defined as possible, an IDM is the summary of several similar use cases. In this case, a Use Case is normatively called a SubIDM.

3.9.2 UCM Service, an offer from buildingSMART International

Over the past few years, many efforts have been made worldwide to describe and identify use cases. The result has been a proliferation of documents, often without a harmonised or even standardised approach. Lack of accessibility and insufficient information on precise classification, status, and maturity prevented comparing similar use cases. Bringing all this activity together in a harmonised way will be of great benefit to the industry worldwide. The BIM methodology can be applied much more efficiently with a service that allows use cases to be developed and classified according to a predefined scheme.

The Use Case Management Service (UCM) was therefore created on the initiative of buildingSMART Switzerland. It is based on a clear vision. The information needs in a project are defined by the sum of all use cases. All participants can use coordinated information consistently, and projects can thus be implemented successfully. This tool provides all stakeholders with a comprehensive basis for digitising their processes and accelerating collaboration. The UCM service promotes the openBIM idea and is characterised by openness and transparency. The development of use cases is a vendor-neutral collaborative process that supports seamless collaboration between all project participants.

Use Case Management is now planned as an integral part of the tools and services offered by buildingSMART International (bSI). The various bSI chapters (country organisations) or bSI rooms (open groups of specialists, e.g., for buildings, airports, bridges, railway infrastructure, etc.) can use the service to develop their specific open solutions and standards. The service is open to the entire construction and property industry. Companies, associations, and institutions can develop their use cases with reference to their own brand/application/company and optionally make them available to the global community.

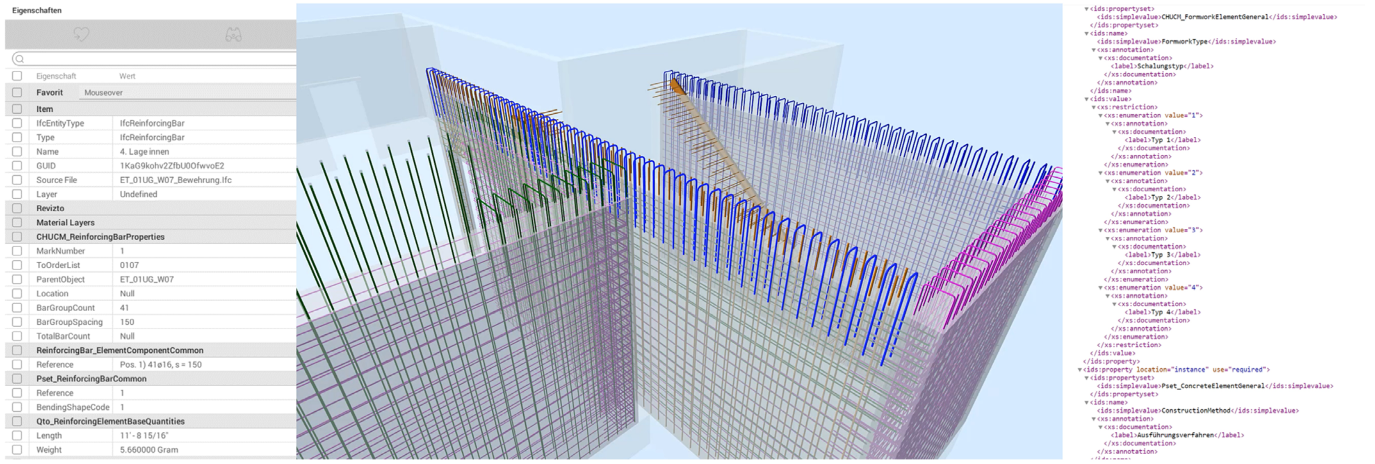
Objectives Use Case Management Service:

- global, vendor-neutral service for experts to collaboratively provide best-practice use cases for the entire construction industry,
- improve the development of digital competence through the use of the BIM method among companies and players in the construction and real estate industry,
- neutral, openBIM-based formulation of use cases,
- establish a common language and understanding of BIM use cases,
- promoting integrative cooperation by defining new, future-proof digital processes,
- creation of a basis for continuous information management and a consistent flow of information over the entire life cycle of a structure,
- provision of machine-interpretable exchange requirements – planned, and
- support and acceleration of standardisation activities of national and international organisations (from best practices to proven practices to standards).

The following figure shows the »Model-based layout of reinforcement« use case with the property sets defined in the exchange requirements and the idsXML export.

Use Case Management Website

Published use cases and other documents (such as case studies, white papers and guides) are available on the UCM website. The download is available to all after free registration. Any user can also add comments. These are collected and forwarded to the project groups for discussion. This supports a continuous improvement process to lay the foundation for future standards.



Co-Creation Space

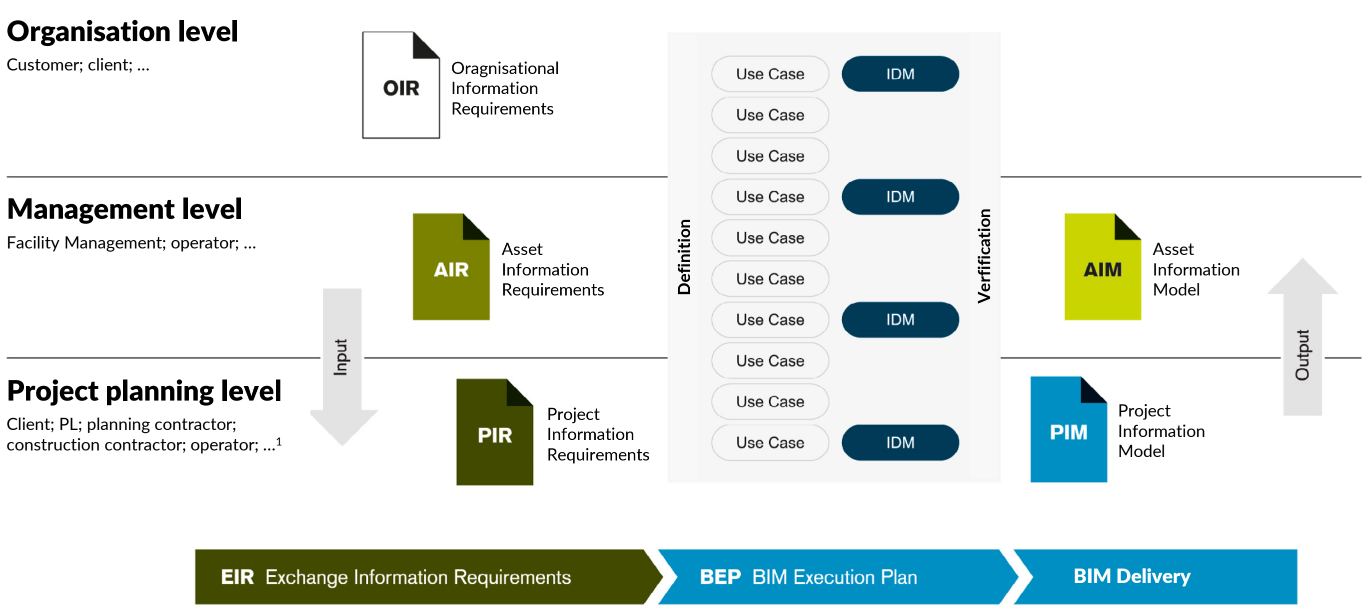
The project groups use the UCM Co-Creation Space (also known as the backend) to record their use cases collaboratively. The aim is to share experiences from completed or ongoing BIM projects and to pool expertise. In this way, a best practice will be generated from individual practical experiences. The platform is structured to guide users through a step-by-step process for developing a use case. The core elements of the Co-Creation Space are:

- use case description:
  defines the content and scope of the information delivery. Delimits the use case, specifies dependencies and gives references,
- process definition:
  Defines who, to whom (actors), what (what information), when (at what time), for what (action to be performed), and how (format/level of detail),
- exchange requirements:
  defines requirements for exchanging information in a format that professionals can read, and
- Information Delivery Specification (IDS):
  the exchange requirements are referenced to IFC and provided in the machine-interpretable Information Delivery Specification (IDS) format.

3.9.3 Information management and use cases in openBIM projects

According to the BIM delivery model (see QR code) of Bauen digital Switzerland / buildingSMART Switzerland, information management is an integral part of project management for openBIM projects (see figure below). Shared project information supports the seamless collaboration of all project participants and facilitates application interoperability throughout the entire lifecycle.

The exchange of information must be regulated between the information requesters and the information providers using Exchange Information Requirements (EIR). The information providers specify the objectives and define the information requirements; the information providers fulfil the corresponding delivery services. In the BEP, the information providers describe the project-specific cooperation concerning planning and information supply. It shows how the client's information order serves the information needs of the other project participants through information deliveries.



¹Depending on the collaboration model

Based on ISO 19650-1, information deliveries are defined in the Organisational Information Requirements (OIR), Project Information Requirements (PIR), Asset Information Requirements (AIR) or Exchange Information Requirements (EIR). To ensure a consistent flow of information, the information requirements of each level should be specified in use cases. These are then summarised in one or more Information Delivery Manuals (IDM).

The use cases available in the UCM service form the basis for both the information provider and the information requester. They are written generically and allow all project participants to have a common understanding and precise definition of information delivery. This greatly simplifies the interpretation of information when ordering or commissioning a project. The information requester selects the use cases relevant to a project and references them in the EIR. During commissioning, the providers respond to the project-specific planning and information requests in the preliminary BEP or after the order has been placed in the BEP. Where necessary, the generic information requirements are specified and supplemented on a project-specific basis. A construction project's project and information management are carried out with the appropriate tools available on the market. The UCM service provides the basis for faster and higher quality ordering and commissioning but is not part of openBIM projects

Lessons learned from openBIM projects can be fed back to the Use Case owner via the comment function of the Use Case Management Service. This ensures that the content is up to date and can be developed further.

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3.9.4 Development of a use case

Initial situation

There are different starting points for developing a use case. The same use case is often used in various BIM projects but handled differently. There is a lack of harmonisation. This leads to inefficiencies and adaptation costs. In this case, developing a best practice use case with different, possibly even competing companies is advisable. The aim is not to exchange company-specific know-how but to define the basic requirements that are generally available anyway.

The second case concerns redesigning conventional applications not yet BIM-enabled into digital use cases. This requires good expertise on the part of the project group and extensive checking of models with different software tools. In this way, the openBIM approach can be ensured.

To exploit the full potential of digital transformation, it is advisable not to migrate existing work processes simply but to rethink them from the ground up and optimise them for the requirements of BIM projects.

Project organisation and project procedure

The best practice approach to Use Case Management is based on an interdisciplinary project team. All domains relevant to a use case must be involved to define the use case collaboratively and integratively.

The project team is organised as follows. The project manager leads the topic and is responsible for coordination. The core team, consisting of max. six people, consists of BIM experts from all domains relevant to the use case. It is responsible for the general description, the process definition, and the non-technical exchange requirements. These must be understandable, i.e., readable, for the end users.

The exchange requirements are then referenced to the IFC by the experts. These are mapped as technical, i.e., machine-interpretable, exchange requirements and are available as idsXML files. For quality control, the use case is checked against BIM models and validated using IDS.

buildingSMART supports project teams using the Use Case Management Service and ensures the formal quality check before publication. However, the technical content of the use case is the project team's responsibility.

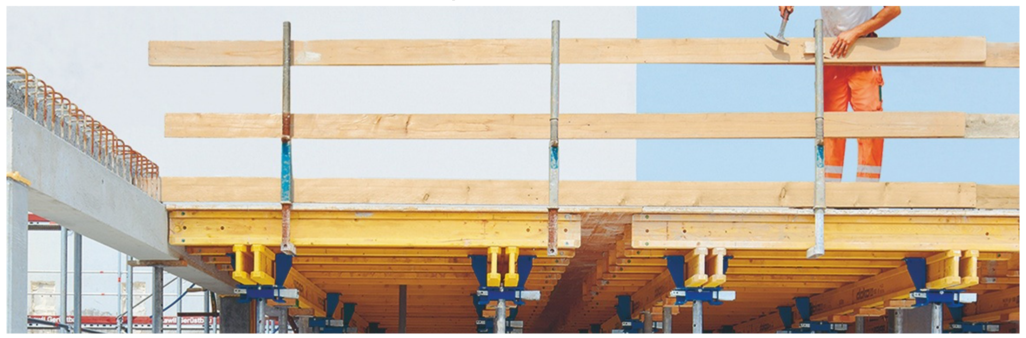
To maximise the acceptance and value of a Use Case, a review team with a base as broad as possible should be involved in the development. This team will provide regular feedback and bring further experience from other BIM projects.

Keep the following points in mind when creating a use case:

- organisation:
  - The organisation responsible for the use case appoints a project manager (PL) and defines the project organisation together with the buildingSMART chapter.
  - buildingSMART creates the project structures in the UCM service.

- kick off meeting
  - The PL creates the »Use Case Definition«. All participants must know the scope, the goals and the necessary delimitations of the use case from the beginning. A precise formulation allows processes to be developed efficiently and targeted.
- BPMN process
  - The project group creates the process flow and defines the requirements for exchanging information based on LOIN.
  - As a rule, the BPMN method is used. This is easy for everyone to understand and enables good visualisation.
  - A use case must be formulated generically and contain no project-specific requirements. This means that generic role models are used instead of specific project organisations.
- exchange requirements
  - The exchange requirements are structured and detailed in tabular form.
- IFC mapping / IDS
  - The exchange requirements are linked to IFC. The different IFC releases must be taken into account.
  - The exchange requirements are exported in machine-interpretable IDS format.
- modelling & checking
  - The domain models required for the use case are created and checked.
- software implementation
  - Various software vendors implement the use case in the native software.
  - The openBIM approach requires the possibility of using multiple software tools.
- checking & publication
  - buildingSMART carries out a formal quality check and publishes the use case.

Example Use Case »Fall Protecion (Absturzsicherheit)«
Suva is the largest accident insurer in Switzerland. Its prevention programs contribute to sustainable improvements in occupational safety. The use of BIM improves the planning and coordination of safety measures. This should help to prevent accidents. Together with buildingSMART Switzerland and an interdisciplinary project team consisting of various specialists, the use case »Fall Protecion (Absturzsicherheit)« was developed.

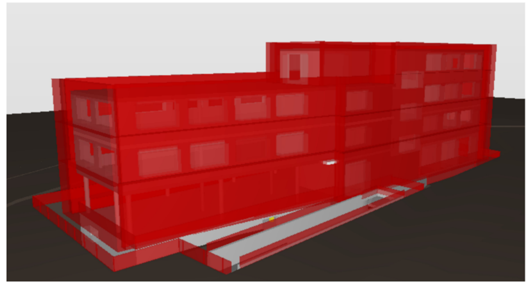
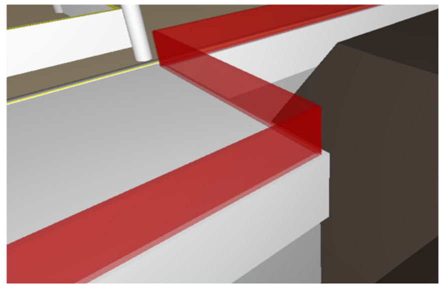
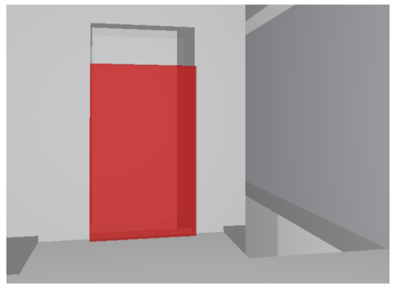


Chapter 3 – In-depth knowledge

BIMcert

3.9 UCM – buildingSMART Use Case Management Service

Examples of the benefits of the use case:
- Planners receive model-based support in the planning and tendering of security measures.
- In the execution model, companies can record the measures to reduce the risks of falling for each construction phase and incorporate them into the work preparation.
- The use of digital technologies promotes the cooperation of all those involved in construction and optimises processes as well as the procurement and provision of information.
- The stakeholders' understanding of the need for occupational safety and health measures increases as the basis for coordinating and implementing safety measures is jointly developed and provided.

Fall protection measures can be checked for completeness in the domain model »Fall Protecion (Absturzsicherheit)«. They form the basis for work preparation and execution on-site. Visualisations facilitate correct implementation on-site. This means the domain model can also be used as an audit tool for safety inspections. Visualising the planned safety measures using mixed reality improves the audit possibilities. Shortcomings in the implementation can be better identified and corrected on-site. In addition, templates for clients, parametric components for modelling, rule sets for model checking, and forms for creating the domain model »Fall Protecion (Absturzsicherheit)« are provided. For modelling, 20 types of fall protection are available in six different software tools as parametric components with a level of detail of LOG100 and partly LOG300.

3.9.5 Outlook Use Case Management Service

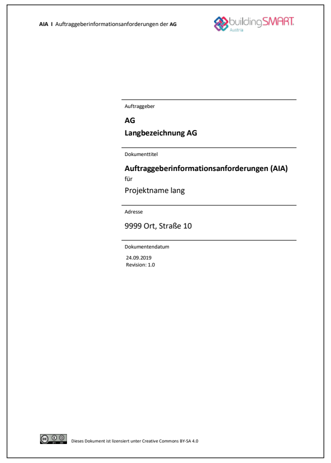
The scope of the service is constantly being optimised, and additional functionality is being added. The focus is on alignment with the technical roadmap of buildingSMART International (see QR code). The next step will be to enable the creation and export of Exchange Requirements as Information Delivery Specification (IDS) files. An interface to the buildingSMART Data Dictionary (bSDD) is also planned. The bSDD referencing will make creating exchange requirements easier and more reliable.

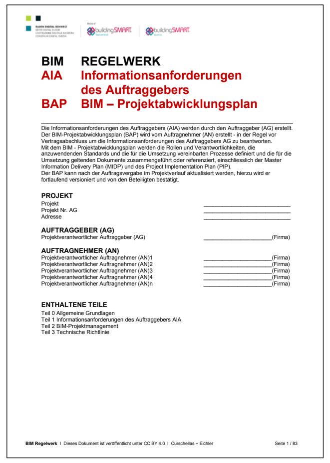
4 BIM project implementation

This chapter provides an in-depth insight into the practical implementation of BIM projects throughout the life cycle phases of a building (in Austria according to ÖNORM A 6241-2): *project initiative*, *project initiation*, *planning*, *tendering*, and *awarding*, and *construction*. It explains the necessary functional steps and activities for openBIM project implementation.

- Relevant for BIM practitioners and BIM experts who want to take a closer look at the individual phases of openBIM use in BIM projekt implementation,
- relevant for all those who want to take the BIMcert practitioner certification exam (equivalent to »Professional Certification Practitioner«) for openBIM coordination and openBIM management, and
- prior knowledge of the contents of Chapter 1, Chapter 2, and Chapter 3 is assumed.

The processes presented in this chapter should always be considered in conjunction with the rules and regulations (EIR, BEP) and service specifications LM.BIM, which are provided free of charge by buildingSMART Austria and buildingSMART Switzerland (siehe QR codes):





Overview of the BIM organisational structure

Section 2.4 provided an introductory description of the roles in the openBIM process. This section places these roles into the context of the BIM organisational structure. The detailed description of BIM project execution is provided in the following sections.

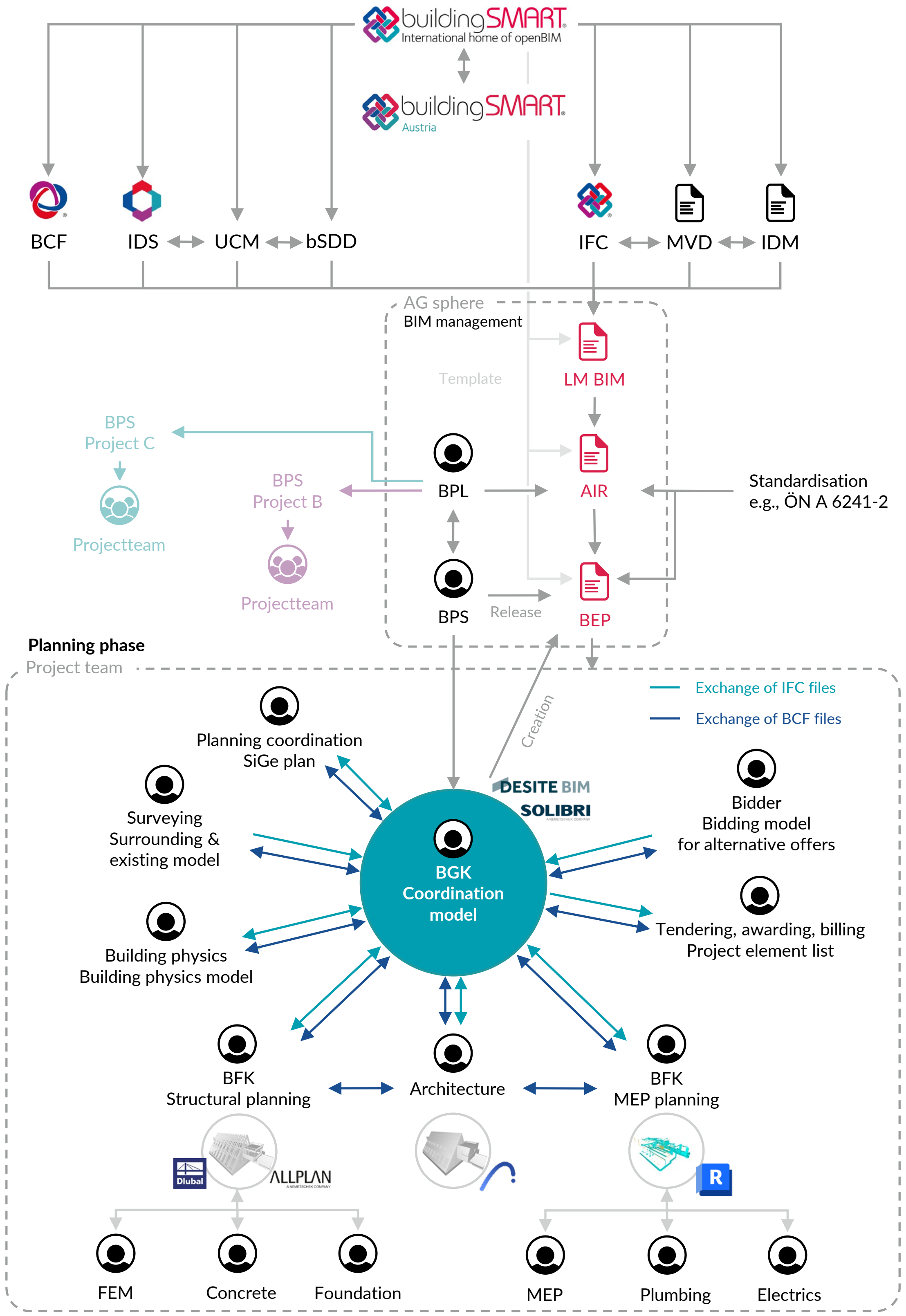
The following two figures provide an overview of the basic BIM organisational structure during the planning and construction phases, respectively. However, an individual organisational structure may need to be developed for each project according to the project-specific framework.

The *BIM project management* (*BPL*) represents the interests of the client with the *BIM project controlling* (*BPS*). The *BPL* is responsible for specifying the framework conditions of the project, defining the service specifications used by the respective players and enforcing the client requirements for the data structure used in the project. It is subject to the creation of the *exchange information requirement* (EIR), in which the client's information are mapped. The EIR should also define and include the information requirements for operation. Within the framework of *openBIM*, the specifications regarding the data to be supplied and the interfaces for data exchange are defined based on the buildingSMART standards. buildingSMART Austria provides templates for sets of rules and specifications. The topic of standardisation is described in Sections 2.5 and 3.1.

The *BPS* is responsible for the operational implementation of the BIM project within the framework of the specifications of the *BPL*. It concretises the EIR within the framework of the *BIM execution plan* (BEP). This is the basis for the BIM-based collaboration. The BEP should be part of the contract between the client and the project team. The interdisciplinary BIM content of the project team is coordinated and verified by the *BIM overall coordination* (*BGK*). This is the contact for digital planning alongside the *BPS*. The *BGK* team is responsible for the coordination model and monitors the execution of the tasks of the respective domain coordinators. The BIM domain coordination (*BFK*) check the domain BIM content of the individual domains.

The organisational unit *BIM Management* (BIM-M) is therefore not further specified. All the following information on the tasks and responsibilities of the *BPL* and *BPS* are the responsibility of the **BIM-M** when it appears in a project and, thus, replaces the *BPL*+*BPS*.

The following figure shows the project team with the project participants during the ***planning phase***. The surveying team creates an environment and asBuilt model, which is available as a basis for architecture, structural design, technical building equipment, and building physics. The various planning domains produce their own domain models. The *BGK* team merges these various domain models into a coordination model. The project participants exchange reference models with each other. In an openBIM process, this exchange of IFC files is also carried out by the *BGK* team. However, depending on the agreement, the transfer can also take place directly between the trades. The model-based communication between the project participants is carried out using the BCF. During coordina-



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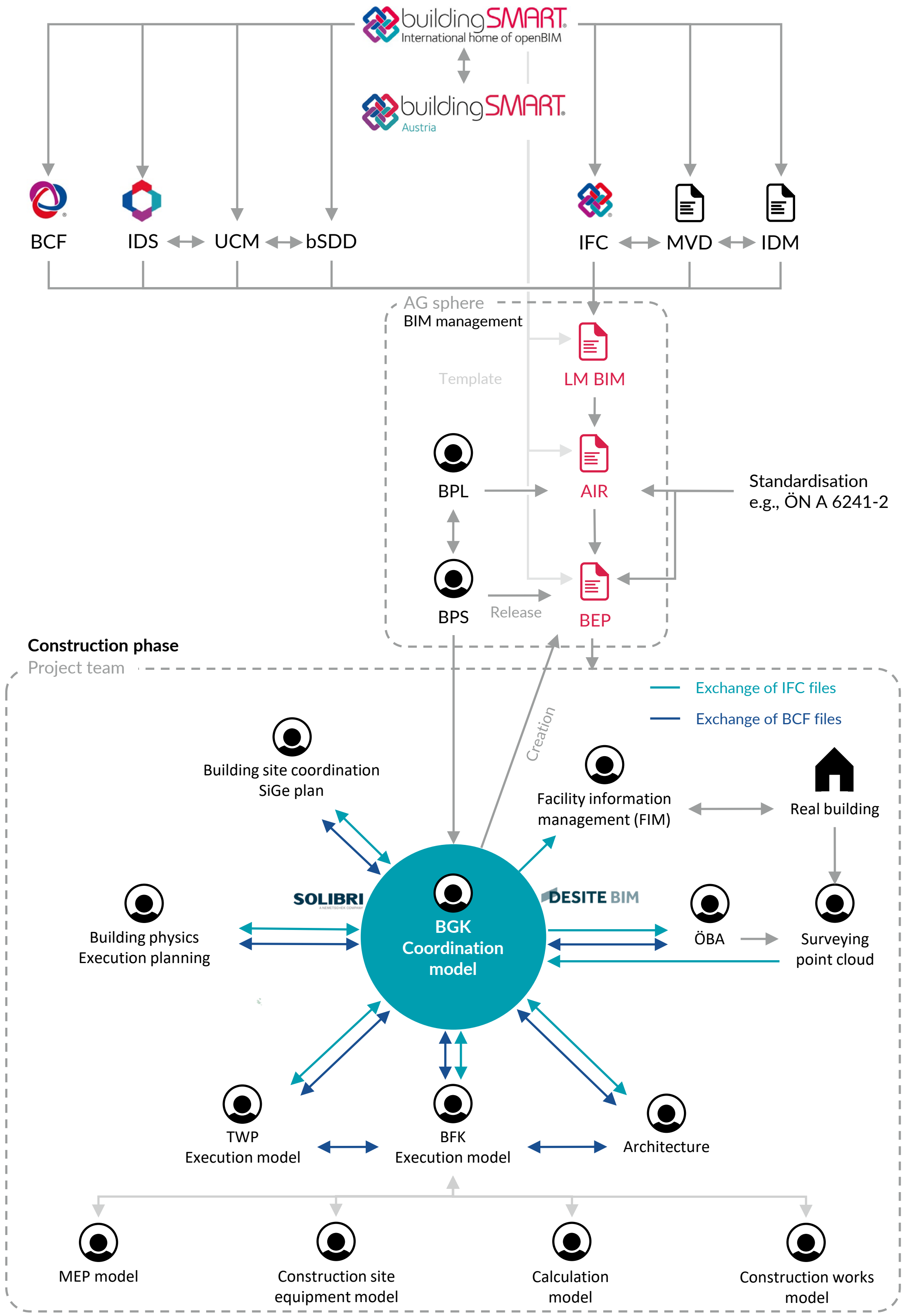

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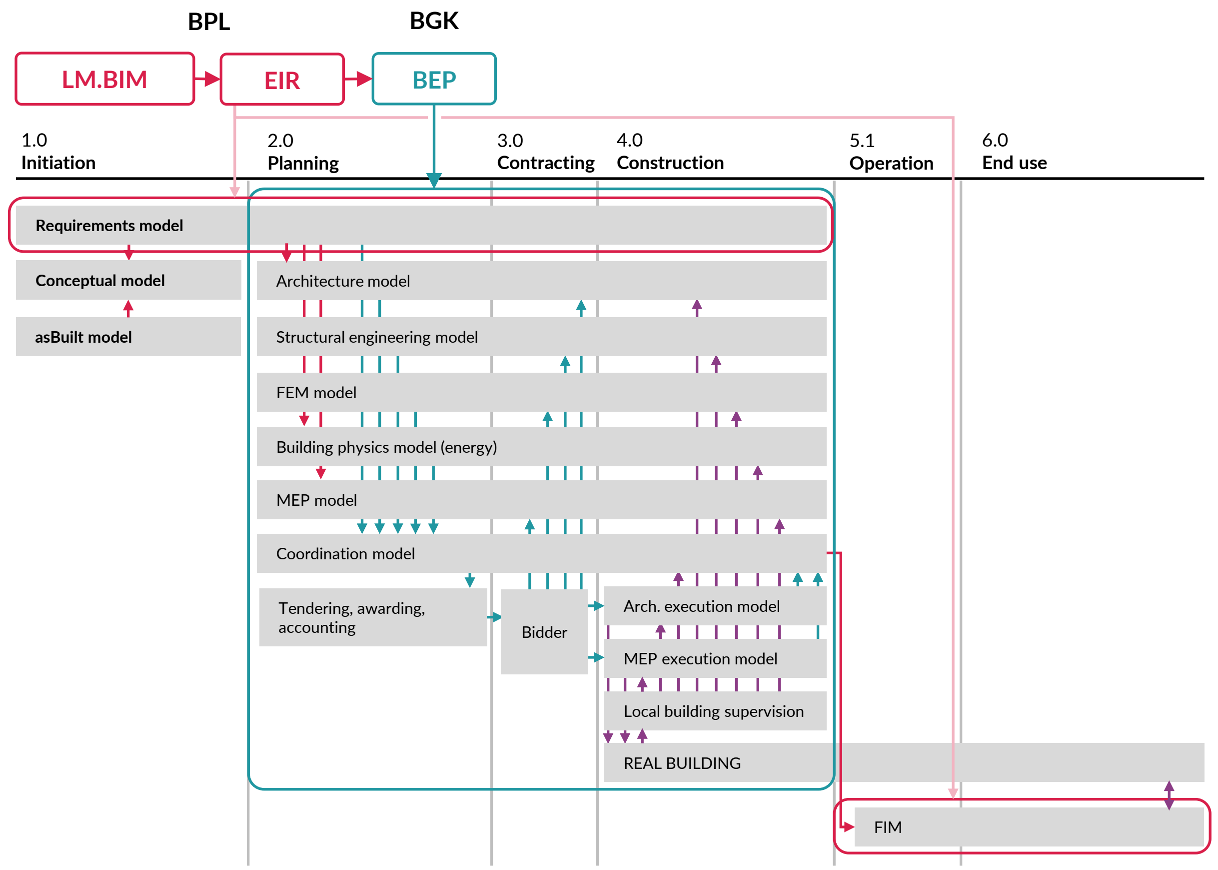
tion, the *safety and health protection plan* (SiGe-Plan in Austria) of the planning coordinator is considered. Currently, the planning coordinator does not create an own domain model for this plan. The coordination model can be used as a basis for tendering, awarding, and contracting construction works. In addition to the modelled elements, the tender model must also consider elements relevant to the standardised specifications for building construction (LB-HB), e.g., construction site equipment and required excavation volumes. Any alternative offers may result in a tender model. In Austria, a structure for a list of elements (*AVA* elements) is currently being developed with ÖNORM A 2063-2. This will link the model to the standard service descriptions and define standardised material declarations.

The second figure shows the project team in the ***execution phase***. Within the scope of execution planning, execution models for architecture, structural engineering, building services, building physics, site equipment, and costing and auxiliary construction measures as well as a SiGe plan are created. The assigned surveying team will carry out the asBuilt documentation during construction. *ÖBA* coordinates the surveying work on site. The resulting point clouds are compared with the domain models using automation. The *BGK* identifies and coordinates any deviations and documents the result in the model. The result is a complete documentation of the asBuilt status using the updated asBuilt models. The asBuilt status is transferred to the *Facility Information Management* (FIM) system, including the updated domain models and technical documentation.

This chapter is structured according to the life cycle phases of *project initiative*, *project initiation*, *planning*, *tendering*, *awarding*, and *construction*. The following figure depicts the organisational structure described above according to the life cyle phases. The basis for the EIR is provided by the service specifications, which specify the corresponding roles and their respective tasks or responsibilities. The LM.BIM and EIR are created in the project initiation life cycle phase once the project organisation structure has been defined. The EIR include requirements for data structure, levels of detail, interfaces, designations, data transfer, and *collaboration platform*. These also consider the operational requirements. In the next step, the *BPS* creates a BEP template. This is based on the project-specific EIR and specifies the exact sequence for implementing the EIR specifications during the project. The BEP colloquium completes the project initiation phase, where the specifications for the model-based project implementation are evaluated with the help of the planning team based on a BEP template. The BEP forms the basis for all communication, collaboration, data exchange, and controlling in the planning, contracting, and construction phases. The BEP is a living document kept up to date throughout the lifecycle. If necessary, the BEP will be adapted as required by the *BGK* under the supervision of the *BPS* and in consultation with the project team. Based on these requirements (red arrows), the domain models are created in the planning phase and combined in the coordination model (turquoise arrows in the planning phase). The bidder information completes the domain models while awarding the contract (turquoise arrows). During the construction phase, the domain models are updated according to the asBuilt status (purple arrows). *BGK* hands over this asBuilt documentation to FIM in accordance with the client's requirements (red arrow).



The life cycle phases are named according to the Autrian standard ÖNORM A 6241-2, Annex B.

4.1 Project initiative

The life cycle phase »Project initiative« is about basic project development. In this phase, the client develops the basic specifications on which the future project will be based. In the process described in this section, the general decision-making process for project implementation takes place – here, the results achieved are used to evaluate the extent to which the project idea can actually achieve the goals and the framework specifications defined by the client, or to assess which capabilities are expected.

4.1.1 Determination of the project-related objectives

This activity is performed at a very early stage of the project by *BPL*, or in a supporting role by *BPS*, and is designed to focus the work of the future contractors on client's benefits.

In the *first step*, the client defines the *strategic objective*. In this strategic document, the client formulates the investment objective, which shows the reasons for the intended investment. In addition to purely quantitative specifications for the investment framework, qualitative specifications are also defined:

- the strategic intent of the client,
- the definition of the investment type,

- the determination of the intended use,
- the determination of the intended service life (staggered according to primary system, secondary system/MEP, expansion),
- the definition of operational objectives,
- the definition of the economic objectives, and
- the specification of standards to be met or intended real-estate certifications.

The *second step* is the definition of the *operational objective* which builds on the framework of the strategic objective. Here, the client formulates his BIM objectives, which show the reasons for the use of BIM. Usually, each defined objective is supplemented by a compact description of the mode of action.

The *third step* is the *prioritisation of the defined operational goals*. On the one hand, this can be done with a simple ranking of the operational objectives according to their importance for the client – or supplemented with a so-called objective matrix, which compares statements on planning-relevant issues that are partially mutually exclusive. The preference determined by the client clarifies his priorities. For example, it can state that the client generally prefers solutions that lead to low operating costs to those that cause low investment costs – or vice versa.

The definition of the objectives is an essential building block of the project concept. On this basis, the definition of the required model content (via LOG and LOI) follows through to the definition of the project-related use cases according to the definition of the LOIN. This procedure controls the overall direction of the project. The prioritisation of the specifications supports the expression of the client's intentions. The aim is to find an optimal mix of intended objectives (with usable added value) and the *actual performance of market participants* (with the resulting field of bidders).

4.1.2 Determination of the financing model

This is done at a very early stage of the project by *BPL*, or with the assistance of *BPS*, and serves to align project outcomes with market requirements. The definition of the financing model is a fundamental building block of the project conception. On this basis, the required model content (via LOG and LOI) is subsequently determined by defining the project-related use cases in accordance with the definition of the LOIN, thus controlling the overall orientation of the project – especially regarding the *requirements of future users*. The client seeks an optimal mix of *required BIM services* (with usable added value) and the *actual performance of market participants* (with the resulting bidding field).

4.1.3 Reconciliation of the performance indicators

The reconciliation of performance indicators is done by *BPL*, or with the assistance of *BPS*, at a very early stage of the project and is used to determine the success of the project implementation.

In the *first step*, the client defines the *target area for measurement*. In doing so, the already developed objectives are used, and a distinction is made between content and processing objectives. In the *second step*, the client determines the *relevant measurement parameters* and *criteria for the target areas*.

Coordinating performance indicators is an essential building block of the project design. On this basis, the project's success is determined, and the primary indicator for the project status is defined. Clients seek the optimal combination of *project-specific focus* (with precise, objective results) and *cross-portfolio comparability*. The key challenge is to identify a data source that can provide meaningful information of consistent quality and quantity throughout the project's life.

4.2 Project initiation

Life cycle phase »Project initiation« is focused on the basic project setup. In this life cycle phase, the client develops the basics for project implementation on which the activities of the contractors are based. This life cycle phase starts after the positive evaluation of the project idea. During this life cycle phase, the concrete specifications for the project implementation are developed and, if necessary, conceptual studies are carried out, e.g., in the form of an architectural competition. The project phase concludes with the establishment of the BIM organisation and relevant steps *before* the immediate *start of project planning*.

4.2.1 Identification and compilation of project-related requirements

Project initiation starts with the identification of project-related requirements by *BPL* and serves to compile these requirements based on company-wide cross-project sets of rules. For institutional clients, the predefined company-wide AIR or EIR (cross-project) serve as the basis. These uniformly declare the general framework requirements with regard to basic uniform specifications for project execution as well as any data transfer (in particular to FM) across all projects (institutional clients are clients who regularly handle construction projects and thus maintain in-house competencies).

In the *first step*, *relevant regulations* are identified. The project location, project complexity and corresponding objectives of the client are decisive criteria. In the *second step*, these requirements are summarised for each project. They are thus available as a basis for the subsequent project-related establishment of the rules and regulations.

4.2.2 Creation and setup of BIM service specifications, rules and regulations, and contracts

In this activity, the *BPL*, possibly supported by the *BPS*, formulates the project-related requirements in rules and regulations. Based on this, the performance specifications for contractors are declared in a form that is customary in the market and uniformly comprehensible. They form part of the invitation to tender and later also of the planning contracts.

The *first step* is to define the basic *organisational structure of the project*. This directly impacts the services to be provided by future contractors. Therefore, the *second step* is to define the service specifications for all *relevant organisational units* – often carried out cooperatively by the *BPL*, *BPS*, *BGK*, and *BFK* teams, the *BIM model designer*, and the *ÖBA*, to fully coordinate and clearly delimit the service specifications. In the third step, the client prepares the EIR based on the service specifications. They define and contain at least the following specifications:

- description of the use cases relevant to the client,
- specifications for the *data structure*,
- specifications for the *levels of detail*,
- specifications for project location and positioning,
- requirements for the *interfaces* to be used,
- requirements for the *designations* to be used,
- requirements for the *data transfers* to be carried out, and
- requirements for the *collaboration platform* to be used.

The *fourth step* is preparing the BEP template, which serves as the basis for the project setup during the BEP colloquium (see Sections 4.2.8 and 4.2.9). The BEP template builds on the project-specific EIR and the exact sequence for implementing the EIR specifications. The chapter structure of the EIR is maintained in the BEP to provide a direct link between the EIR and their implementation in the BEP. In the final step, the developed specifications are integrated into the tender documents.

4.2.3 Model-based requirements planning (requirements model)

BPL or *BPS* now formulate the project-related requirements for the structure to be created. The difference to a conventional space and function program lies in the semantics of the requirements model and the associated machine readability. This allows, on the one hand, for the seamless transfer of the client's specifications by the planning team (= *planning contractor*) into the respective BIM application and, on the other hand, for the automation-supported verification of the specifications from the requirements model against the current planning status during the project. The requirements model is a performance specification for the *planning contractor* and therefore part of the tender.

Requirements models are created using specially developed tools such as *dRofus* or *buildingOne*. These tools enable the concentrated development of the layout and function programs as well as the corresponding organisation of room types including equipment options. They can map these specifications in an IFC-based structure. The specifications for the IFC structure are taken from the AIR or EIR and must conform to the data structure to be used later in the project by the *planning contractor*. Otherwise, a comparison between the requirements model and the planning models is made difficult or impossible.

The requirements model quantitatively maps all spaces to be considered in the planning, including the qualities to be created. These are then responded to by the *planning contractor*. The requirements model can be initiated by the *planning contractor* and updated in the planning context. The original requirements model remains the responsibility of the client; the *BPL* updates it in appropriate cases. A change to the requirements model is traceable and communicated accordingly. Under certain circumstances, this change is a formal amendment to the order and may result in a planning change. The interaction of planning specification with planning implementation thus becomes more transparent and comprehensible.

At a minimum, the comparison of the requirements model with the planning models takes place during the checks for data delivery (reaching a QualityGate).

4.2.4 Basic structure (survey, asBuilt model of existing building, terrain model)

The *BPS* team, possibly together with the surveying team, creates the project-related planning basis during the basic design. The difference to the conventional approach lies in the significantly higher precision of the specification (georeferencing, complete mapping of the existing situation, structural specification, and functional scope). This facilitates the seamless use of the asBuilt information of the existing buildings by the *planning contractor* in his/her BIM software applications. The asBuilt model and terrain model are part of the tender and the basis for any conceptual studies or architectural competitions.

4.2.5 Tendering, awarding, and installation of the collaboration platform

During project initiation, *BPL* and *BPS* create the central platform for information exchange. Institutional clients use predefined, company-wide, and standardised product specifications as the basis for all projects.

In the *first step*, the client identifies the *relevant functions*. The key criteria here are user rights, the resulting security aspects, the type of project, and the complexity of the project. The *second step* summarises these *requirements on a project-specific basis*. If the client does not require a specific product, the next step is to invite tenders and procure a collaboration platform in accordance with the specifications. Once procurement/awarding has been completed, the *third step* is the *project-related setup*. The organisational unit responsible for this is the one that will later be responsible for project management (usually *BPS*).

At present (2023), the functional scope of some collaboration platforms already includes the bidirectional, web service-based handling of model-based communication (BCF) and model exchange (IFC) based on *openCDE*. This enables direct connection of BIM applications to the collaboration platform and seamless information exchange. This eliminates the need for manual steps to provide or obtain information. This significantly accelerates collaboration during project execution.

4.2.6 Tendering and awarding of planning services

BPL and *BPS* identify the best bidder for the planning services. In the *first step*, they compile the previously developed *basics* (rules and regulations, specifications, requirements model, asBuilt basics). In the *second step*, the most suitable *tender strategy* in the context of BIM is determined (single-stage, two-stage, loaded, open). The current market environment must be compared with the required scope of services. The goal is to narrow down the selection to a compact array of bidders – potential contractors who are both BIM-capable and suitable for the project objective. In the *third step*, the *tender criteria* (openBIM, proof of qualification of the contractor) must be developed. The client defines the required qualitative suitability of the bidders (BIM competence, references, BIM applications) as well as the mechanisms for ensuring that this requirement is met. It must be ensured that the defined requirements allow a *broad range of bidders* to apply (i.e., are as *low as possible*) as well as *guarantee reliable project implementation* (i.e., are as *high as possible*) – and this always requires a compromise.

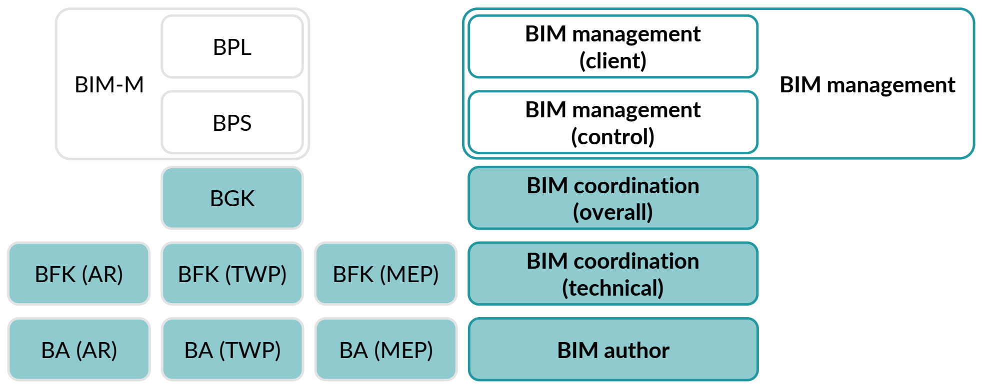
During the tendering and awarding process, various interview sessions are held with the bidders. Due to the currently still heterogeneous knowledge of BIM across the board, these often require extensive questionnaires that must be answered competently by the *BPL* and *BPS*.

4.2.7 Conducting model-based studies/competitions

This activity is prepared by *BPL* and *BPS* during project initiation and serves to find the best idea for project implementation in terms of content. BIM usually plays no or only a rudimentary role here.

4.2.8 Structure of the planning team

BPS presents and explains the developed basics (sets of rules, performance specifications, requirements model, asBuilt basics) to the future *planning contractor*. This step is necessary to clarify all interrelationships and requirements by mutual agreement and thus to establish a uniform view of the project requirements for implementation in the entire project team. This activity takes place in the *first colloquium*. At this time, the *planning contractor* also announces how the persons for required BIM organisational units will be selected.



Then the *BEP colloquium* takes place. In this meeting, the *planning contractor* determines how the client's specifications will be implemented and in which steps this will be done. The results of this colloquium lead to the BEP. The *BPS* supervises the preparation of the BEP, while the *BGK* of the *planning contractor* is responsible for its content.

Negotiations for the planner contracts often accompany these activities. The colloquia are conducted by the *BPS* and serve to evaluate the existing BIM skills of the *planning contractor*. At this point, at the latest, *corrective action* regarding qualification must be requested – or the fee can be used to intervene.

4.2.9 Setting up the project model (PIM) by means of BIM colloquia

During a *modelling colloquium* organised by the *BPS*, the model-based project execution (BEP) specifications are evaluated. The *planning contractor* implements the specifications from the BEP in extracts using a sample model and works through relevant use cases as examples (if the BEP is not yet available in the sufficient form at this point, the EIR or the sample BEP is used as a specification). This procedure ensures the basic feasibility of the specifications and defines relevant content for model-related collaboration within the planning team.

These steps must be completed before planning to avoid confusion between BIM creation and planning execution:

- ensuring that the *project location/project direction* is used consistently,
- ensuring the use of a uniform *floor/storey structure* and *grid structure*,
- the detailed coordination of the *IFC transfer configuration* in the context of the BIM applications used to ensure the intended collaboration,
- ensuring the required knowledge for model creation/transfer (modelling and implementation of the specifications for LOG and LOI), and
- ensuring the knowledge necessary for model coordination/communication.

As the *modelling colloquium* (like the *EIR/BEP colloquium*) will also take place during the negotiation of the design contracts, both colloquia will provide an opportunity for the *BPS* to review the *planning constructor's* qualifications in detail. The *BPS* will provide the *BPL* with the results of both colloquia, including an assessment of the *planning constructor's* capabilities. In particular, the modelling colloquium offers an opportunity to gain insight into the existing communication and software skills of the planning constructor per domain: Deficiencies in communication skills or in the use of the *planning constructor's* own software can be identified in good time. For example, additional training on the software can be requested, or an update to a more recent version of the software can be requested to achieve better performance. If the *planning constructor* of an individual domain is unwilling to do this, the *BPS* must inform the *BPL*. This will directly impact the negotiations and may lead to the exclusion of a domain.

The colloquia can be repeated if more project participants are added during the project phases.

4.3 Planning

Life cycle phase »Planning« is used to develop the planning specifications for tendering, awarding, and construction. The service phases of planning comprise the preliminary draft, the design, and the submission planning including the approval procedure. This section considers the content of these service phases. In general, there is no difference between the basic services and software applications within planning – only the scope of the services increases in each successive project phase due to the phase-related specifications. All requirements regarding the content to be provided and the services to be performed are to be defined by the *BPS* and *BGK* teams in the EIR or BEP rules and regulations before the start of planning and can be further differentiated during the project.

This section considers the steps and definitions required at the start of planning and describes the use cases usually carried out by the *BGK* and *BFK* teams and the BIM author in projects in the course of the work to be performed.

4.3.1 Handover of the basics and documents to the planning contractor

At the beginning of the planning phases, the planners involved in the project are provided with the previously determined and generated basics. This is done via the collaboration platform (CDE). The following serve as the basis for planning:

- terrain model,
- asBuilt model of existing buildings (if buildings exist and are to be used), and
- requirements model.

The first two models are to be determined (or created) by the survey and transferred as a 3D model (see also Section 4.2.4). The point cloud produced by the surveyor and, if necessary, supplementary planning documents (valid as-built plans, formwork plans) serve as a good basis for creating the models. With the handover of the models, the responsibility also changes from the creator (surveyor) to the *planning contractor*.

The client's representative creates the requirements model (see Section 4.2.3) and forwards it to *planning contractor*. The authorship remains with the client. The requirements model is integrated in the coordination model to serve, if necessary, as a reference during the planning process to carry out the corresponding target/actual comparison with the planning models.

All model basics are provided as IFC files. The asBuilt model, however, is provided in the native format of the BIM software application to ensure that further processing by the *planning contractor* is as loss-free as possible. However, the BIM software application of the *planning contractor* must be known at an early stage (at the time of model creation), which is not possible in every project, e.g., when conducting architectural competitions. In such competitions, a different strategy is used, in which the performance boundary between surveying and *planning contractor* is shifted. In such cases, the surveying department only provides the corresponding point cloud and *planning contractor* is responsible for the creation of the asBuilt model based on this data. The problem of the BIM

software application having to be known at an early stage is eliminated. Any differences in the scope, detailing, and focus of the asBuilt model are also obsolete.

Regarding the actual implementation: at the beginning of planning, the respective *BFK* team must ensure that the supplied models can be used correctly by the other *planning contractor* – regarding location (georeferencing) and element definition (IFC entity). Usually, only the domain architecture team adopts the terrain model into its authoring software. In the case of asBuilt models, it can be specified which domain has to implement the corresponding basic information. This depends on whether the asBuilt model contains the building shell, the extended building stock, or also building services information. For example, the shell of the building can be assigned to the domain of structural engineering, the developed building stock to architecture, and the building services elements to building services planning. Such a differentiated transfer of asBuilt model content must be coordinated and defined before the start of planning. This is done at the latest when the BEP is developed in the corresponding colloquium (see Sections 4.2.8 and 4.2.9).

During planning, the individual domain models of the domains involved in the project are then created based on the basic models.

4.3.2 Structure of the model basics

The PIM (project information model) consists of the various domain models of the respective project participants and their domains (in Austria, see ÖNORM A 6241-2). These are also referred to as planning models.

The basic models adopted at the start of planning (terrain model, asBuilt model of existing buildings) remain part of the respective domain models (see Section 4.3.1). The responsibility for establishing model-based collaboration usually lies with the domain of architecture.

Overriding specifications can be made for all domain models used in the planning phase for planning, which facilitate their coordination and further use. In general, the BEP defines the following information for all domain models

- clear responsibility for a domain model and its content,
- default for domain model naming,
- specification of the project coordinates and project direction,
- specification for floors/storeys and floor/storey zero,
- specification for modelling the model content, and
- specification of the levels of detail of the domain models (LOG, LOI).

These general specifications are explained in more detail below.

Clear responsibility for a domain model and its content
All domains involved in the project that maintain their own domain model are responsible for all content of the respective domain model. The respective *BFK* team is the responsible party. It ensures the qualitative composition of the provided domain model regarding the specifications. The *BFK* team is the responsible contact entity for the coordinative and implementation tasks.

Different model content is to be created for each domain model:
- domain model architecture,
    - architectural planning including
        - outdoor facilities,
        - interior design,
        - fire protection, and
        - building physics;
- domain model structural engineering,
    - structurally relevant construction elements; and
- domain model MEP (division into individual sub-models)
    - sub-model MEP planning/heating,
    - sub-model MEP planning/ventilation,
    - sub-model MEP planning/sanitary,
    - sub-model MEP planning/electrical, and
    - sub-model MEP planning/ICT planning.

Model information from project participants who do not maintain an independent domain model can be transferred to the model-managing body by means of BCF comments. This applies, e.g., to fire protection and building physics data, which can be transferred to the architecture in this way. The responsibility for the content of the data remains with the supplying domain. The receiving domain is only responsible for the implementation of the information in the model (checks are carried out by the *BFK* team responsible for the model).

Default for domain model naming
Each domain model (as well as any submodels) must have a unique name. The name is constant over the entire course of the project – it does not contain any date or version information. The CDE regulates these two indicators (date of upload or versioning systems within the CDE).

In the EIR or BEP sets of rules, a specification for the naming of the domain models must be created, usually following a simple coding system. Part of the coding should always be:
- the abbreviation of the project,
- the abbreviation of the author or the responsible body,
- the abbreviation of the domain model or, if applicable, of the submodel, and
- the abbreviation of the transfer configuration (see Section 4.3.3).

The naming convention should exclude the use of special characters and spaces and conform to CDE specifications.

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4.3 Planning

Example of the domain model architecture:

Abbreviation for:			
Project	Author	Subject model	Transmission configuration
PRJ	ARC	FM	UK1
Ergebnis:	**PRJ_ARC_FM_UK1**		

Specification of project coordinates and project direction
All domain models must be transmitted in the correct position relative to each other. For the definition of the necessary project coordinates and the project direction (deviation from geographic North), the corresponding specifications are created in the BEP before the start of planning (see Sections 4.2.8 and 4.2.9). In Austria, ÖNORM A 6241-2, Annex A (normative) gives the following specification: The building model must be provided with a clear reference point, related to height in meters above the Adriatic Sea, and with a vector defining the deviation from North.

In new construction projects, the architecture model usually takes on the task of implementing the location information. It then rolls it out to the other domains during the first transfer of the architecture model. In some cases, a hybrid strategy is used in which the leading architecture model is georeferenced in the higher-level measurement network (e.g., Gauss-Krüger) while spanning a local compact measurement network with the zero point on the A/1 axis defined for collaboration with the other domains. This allows not only a complication-free collaboration within the planning team but also an exact integration of survey results from the construction site (e.g., point clouds).

Specification for floors and floor zero point
In addition to the general definitions of the floor structure (see Sections 4.2.8 and 4.2.9), the specific floors and their designations in the BEP must be defined on a project-specific basis at the start of planning and implemented equally in all domain models. All domain models must have a uniform floor structure. Any deviation in the designation (including floor code), the number, or the floor height between the individual domain models (transmitted via IFC file) is not permitted and is the responsibility of the respective *BFK* team. Important note: Within the native domain models, additional floors/reference planes may be used; however, these may not be passed on.

In Austria, ÖNORM A 6241-2, Annex A (normative) gives the following specification regarding the floors of buildings: All parts of a floor must be at the same level. The distance between floors must be greater than 1.50 m (in Austria, see ÖNORM EN 15221-6). The reference point of each floor (floor zero) must also be defined in the BEP.

In Austria, ÖNORM A 6241-2, Annex A (normative) gives the following specification: The reference plane of the floors is linked to the top edge of the floor (excluding floor screed).

The following requirement applies mainly to new construction projects:

- The top edge of the floor (excluding floor screed) is to be used as the zero point of a floor, in Austria in accordance with ÖNORM A 6241-2.

For projects on existing buildings (e.g., conversion, renovation), the floor datum can be defined as follows if the top of the rough slab cannot be determined:

- The top edge of the last step of the main staircase is to be used as the zero point of a floor – this level can most likely be determined even after reconstruction.

Default for modelling the content of the model
The following basic modelling principles apply to the uniform structure of the domain models:

- We model as it is built.
- We model only as detailed as needed.
- We model in such a way that changes can be made with as little effort as possible.
- We model elements in structural composite systems as long as this yields benefits for the entire planning team.

In Austria, ÖNORM A 6241-2, Annex A (normative) further gives the following specification: All building elements are to be subordinated to the floor structure, since their construction and use is based on the accessibility for people. It follows that:

- the model elements are to be modeled floor by floor (link is to the original floor and no extension beyond).

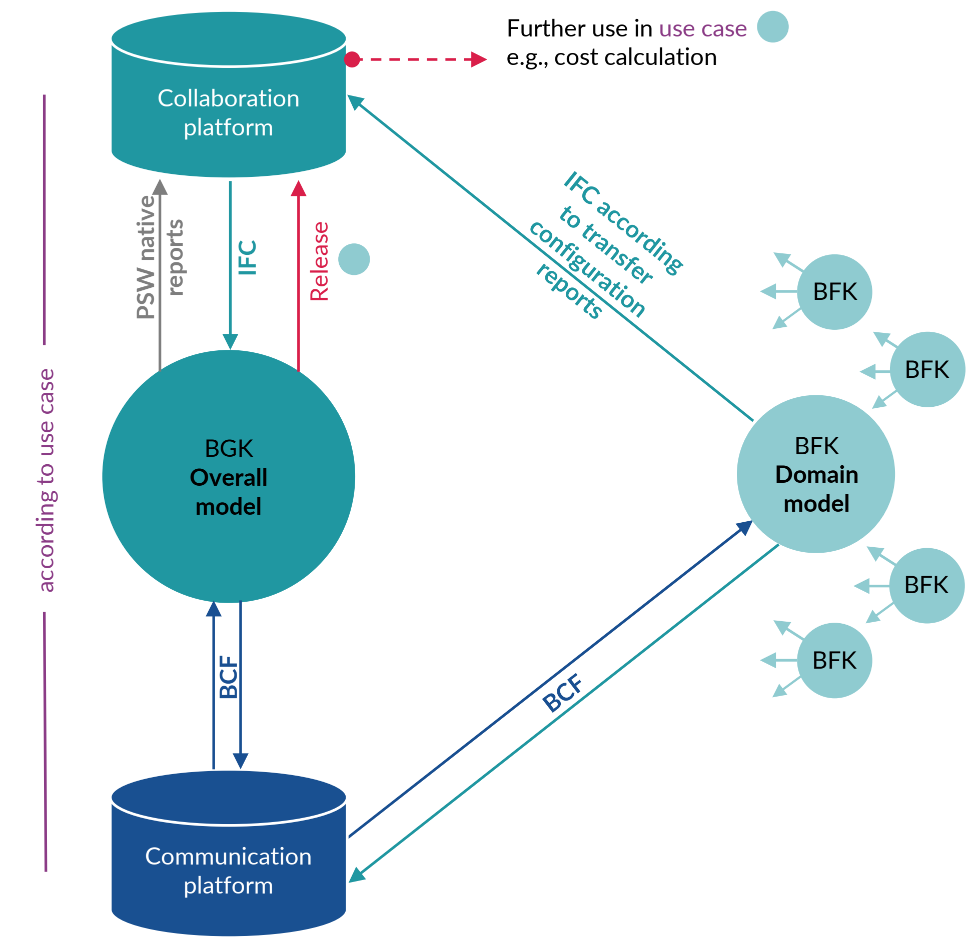
In Austria, ÖNORM A 6241-2, Annex A (normative) also provides a clear illustration for structuring the elements to be modeled. The figure on the following page is taken from the book »BIM-Leitfaden – Modell und Struktur« (Eichler), which clearly shows the elements.

The formulation of the geometric (LOG) and alphanumeric (LOI) content requirements for the domain models for data exchange and further use of the model data is found in the EIR or BEP – while compiling the project-related use cases.

In the planning phases, the intended content of the LOG and LOI is transferred to the domain models in the relevant authoring software as the model content is created.

4.3.3 Establishment of collaboration

The actual model-based collaboration starts with the first transfer of domain models. The *BGK* team uses the domain models for the coordination of these very models. Furthermore, each domain can add the domain models of another domain in its own software as a reference or independently interact with the domain model data in checking software for coordination by the *BFK* teams.



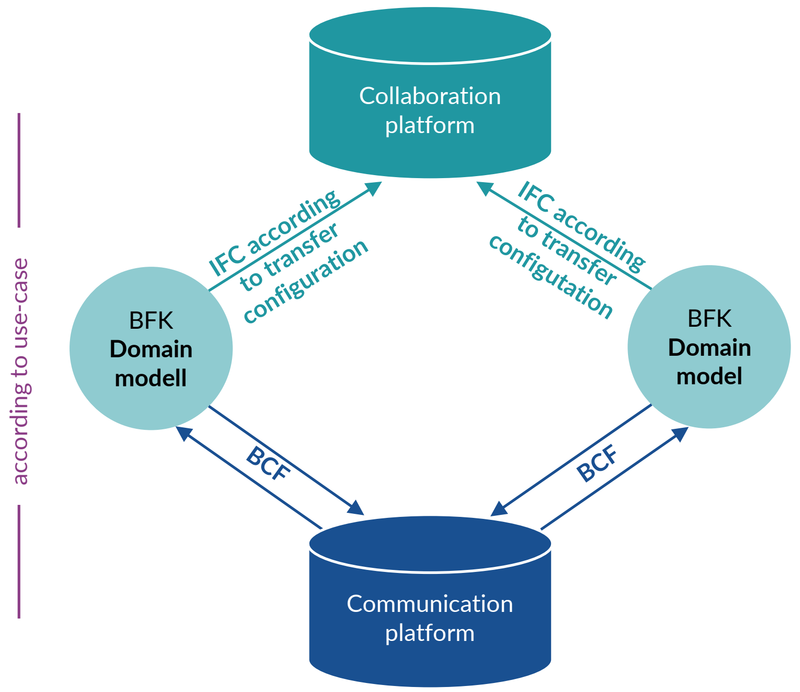
Initially, the main focus is on the correct location and structuring of one's own model. However, the focus quickly shifts to the actual planning content, which can be captured more quickly than in the conventional planning method (2D plans) thanks to the three-dimensionality of the model data. It should be noted here that not only comprehensive domain models and domain models released by the *BGK* team can be used as a reference among the domains, but also parts of domain models or intermediate states which can be employed selectively for situational coordination (both in the authoring software and in checking software).

The type and scope of collaboration in the *planning contractor* team must be defined in the BEP and described in so-called reconciliation cases:

- reconciliation at the end of a phase/milestone (datadrop):
  - responsibility: *BGK* team
  - participants: *BFK* and *BPS* teams
  - content: reconciliation at the end of a project phase or milestone with all domain models
  - time: once per project phase/milestone according to schedule
  - goal: data delivery

- reconciliation during a phase (recurring coordination meeting):
  - responsibility: *BGK* team
  - participants: *BFK* and *BPS* teams
  - content: regular reconciliation
  - timing: ongoing predefined rotation according to schedule
  - goal: coordination of the domain models

- reconciliation meeting as needed:
  - responsibility and parties involved: *BFK* teams
  - content: selective/situational coordination according to a specific need; no overarching coordination by the *BGK* team
  - timing: as needed, ongoing as required
  - goal: reconciliation between two domain models



A checking configuration can be specified depending on the reconciliation case. This determines which checking routine (see Section 4.3.4) is used in the reconciliation case. The assignment of checking configurations to reconciliation cases can be done as follows:

- reconciliation at the end of a phase/milestone (datadrop): checking configuration 3 (**CC3**) = Execution of all checking routines

- reconciliation during a phase (recurring coordination meeting): checking configuration 2 (**CC2**) = Execution of all test routines that must be checked geometrically and alphanumerically at the time of coordination – e.g., the check of the cable routing (building services) against load-bearing walls (architecture and structural engineering) can only be carried out if the penetrations (= construction details) have been coordinated and approved beforehand.

- reconciliation as needed:
  - checking configuration 1 (**CC1**) = Execution of individual domain-specific check queries, to reconcile 2 domain models between the coordination meetings (e.g., reconciliation of construction details between building services and architecture).

Regardless of the type of reconciliation case, certain basic conditions must be met and defined in advance in the BEP:
- compliance with the responsibilities per domain model,
- compliance with the defined interfaces (IFC, BCF, DWG/DXF, PDF, XSL) (see Section 4.2.1),
- use of the specified collaboration platform (CDE) (see Section 4.2.2),
- use of the specified communication platform (for BCF) (see Section 4.2.2),
- use of the defined transfer configurations, and
- compliance with the specifications from the use cases (see Section 4.3.4).

It is very important for collaboration that the required data are created or exported according to the use case (use of model data). Therefore, it is necessary to describe the corresponding **transfer configuration** in the BEP.

A transfer configuration must:
- be uniquely named (abbreviation) (e.g., for use in domain model naming),
- define a unique creator,
- define a unique recipient,
- define the model type (e.g., checking model, shell model),
- be assigned to an MVD (e.g., coordination view, reference view),
- define the model content (e.g., all building elements except furniture),
- define the component setting (e.g., complete, core supporting elements only), and
- define the setting of multilayer components (e.g., composite, broken down into individual elements).

For big and medium reconciliation cases, the following further applies:
- compliance with the defined release process (see Section 4.3.5).

The transfer configurations are determined during the coordination between the planners at the beginning of planning. A check run (e.g., colloquium, see Sections 4.2.8 and 4.2.9) helps to consider the different use cases and the respective planning software regarding the necessary export settings and to define the required content of the final transfer configuration. More necessary transfer configurations can be added if more project participants are added during the project phases.

4.3.4 Performing model management/BIM quality management

The execution of model management is a use case that takes place at different levels of responsibility and at different depths. This use case is often also referred to as BIM quality management or BIM quality assurance – and it is often understood to include the well-known collision check. However, to be able to map it completely, more extensive check criteria as well as the definition of a coordination plan and a data delivery plan are required.

Coordination plan and data delivery plan

A coordination plan is created for the recurring coordination meetings mentioned in the BEP. It describes the composition of the data to be transmitted for each project phase to permit the coordination meetings to be held (see Section 4.3.5). These data are to be provided by the respective *BFK* teams on the collaboration or communication platform.

According to the coordination plan the following information must be transmitted:

- IFC domain models (pre-checked by the *BFK* team)
    - according to the specified designation,
    - according to the specified transfer configuration,
    - according to the specified level of detail (LOG + LOI),
        - in the current state of work,
- BCF comments from the *BFK* teams (from their own preliminary review or from requests to the other *BFK* teams), and
- PDF check report of the own preliminary checks.

The data is always sent to the *BGK* team well before a coordination meeting. This ensures that the *BGK* team has enough time to carry out a quality review. The specific dates for the coordination meetings must be coordinated with and approved by the *BPS*.

The BEP specifies the data delivery schedule to distinguish between the case of recurring coordination meetings and those at the end of a phase (milestone). The specifications for the data to be delivered at the end of a project phase/milestone are defined for data delivery in big reconciliation cases. The main difference between the data delivery plan and the coordination plan is the much higher level of checks (checking criteria) for data delivery. These are intended to ensure the actual delivery of the required model content (achievement of QualityGate) and are related to payment releases from the client.

For the data delivery schedule, the transfers mentioned above for the *BFK* team are supplemented by:

- IFC domain models,
    - released by the *BGK* team after the final coordination meeting,
    - according to the specified level of detail (LOG + LOI), and
    - in the complete state of elaboration.
- plan documents in PDF and DWG/ DXF derived from the domain model:
    - The plans must correspond to the checked and approved status of the domain model (IFC file). 2D information that is only contained in the plan documents (e.g., dimensions) must not contradict the information in the domain model.
- supplementary information (e.g., detailed plans).

The *BGK* team delivers according to the data delivery plan:

- released coordination model (in the format of the checking software),
- PDF check report, and
- classification scheme of the check results (see Section 4.3.5),
    - including assignment of the check results to the passing of a necessary QualityGates.

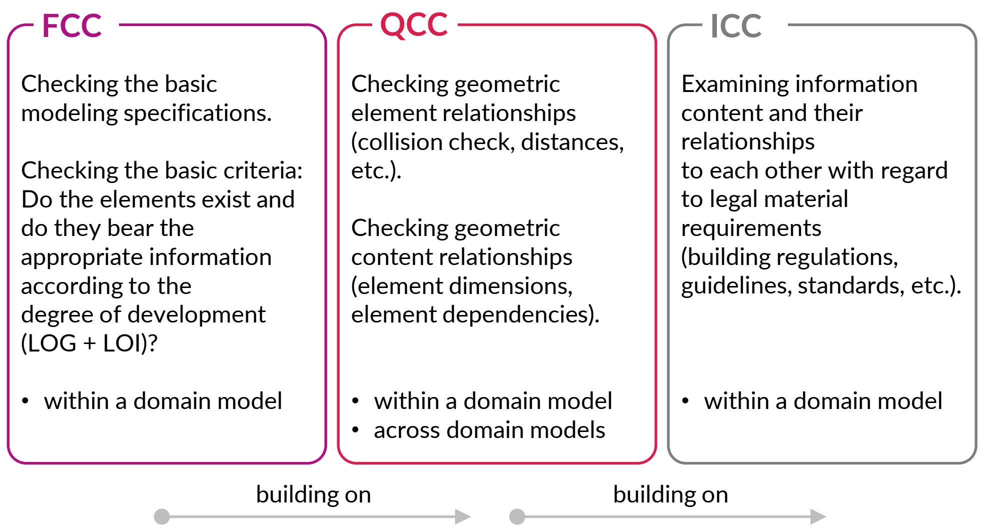
The *BPS* team specifies the dates for the final coordination meeting at the end of a project phase or milestone and the associated data delivery. They must be coordinated with the *BGK* team and the project schedule.

BIM quality management

The EIR or BEP must describe the requirements for model-based quality management or the concrete implementation for uniform quality control and coordination of the digital models. The description includes the specifications for the checking criteria (= checking routines) that must be implemented in the checking software.

The checking criteria are classified according to different focal points, which serve to organise model checks and make the check results assessable. The system of criteria checks comprises:

- Formal Criteria Checks (FCC),
- Quality Criteria Checks (QCC), and
- Integrity Criteria Checks (ICC).



This structure and its systematic content were developed by Tina Krischmann and Hannes Asmera in 2016 and can be found in many specifications for checking routines.

The FCC include:

- basic modelling specifications:
    - elements are present and relatable to each floor and
    - GUIDs are available only once, and
- degree of elaboration:
    - LOG: elements modeled according to LOG class, e.g., single or multi-layer and
    - LOI: elements are correctly classified according to their IFC entity and carry the required characteristics according to their LOI class. The value range of the characteristics is meaningful (e.g., according to a default option, contains a range of numbers, contains a true/false value).

The QCC include:

- geometric element relations:
    - elements do not overlap (collision check) or the overlap is within the specified tolerance, and
- geometric content relationships:
    - elements have a required minimum or even maximum distance:
        - e.g., minimum distance from sanitary objects to manholes, and
        - e.g., maximum distance from shafts in adjacent floors.

Regarding the QCC, it should be noted that the *BFK* team carries out these checks internally within the domain model, while the *BGK* team carries them out both internally within the domain model and across domain models.

The ICC include, among others:

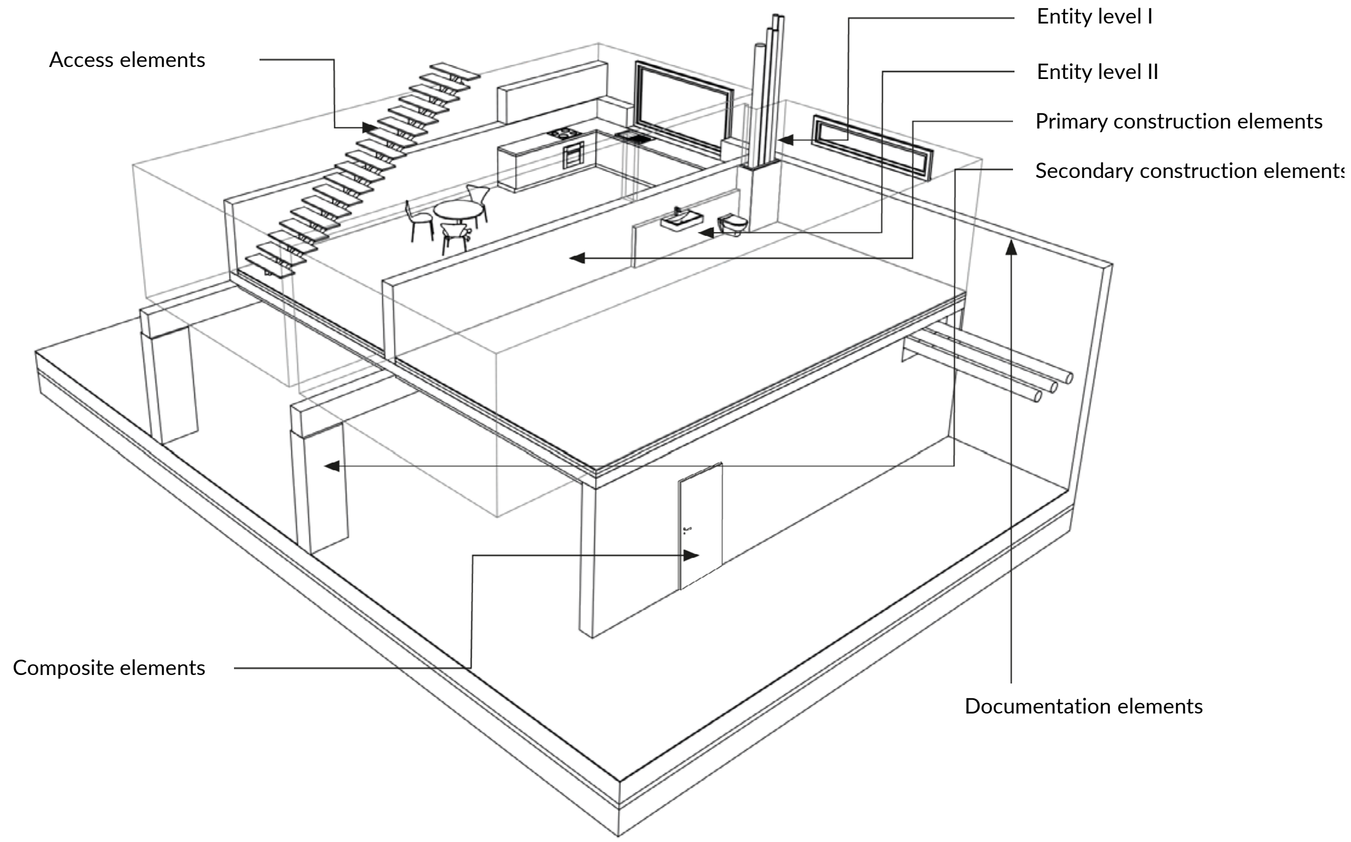
- mathematically mappable legal matter requirements,
    - e.g., escape route width and escape route length and
- relationships from legal requirements,
    - e.g., required number of barrier-free parking spaces.

In Austria, compliance with norms and standards is the responsibility of the *planning contractor* due to their qualification as state-certified technical experts. Therefore, verifying the ICC in the respective domain model is the responsibility of the *BFK*, whose normative specifications define the requirements for this. The *BGK* and *BPS* can conduct ICC inspections, but only to randomly check compliance with normative requirements.

In the case of the ICC, it should be noted that the local legal requirements must be strongly considered. At present, only the technical building requirements can be partially mapped but not the legal building requirements (= neighboring rights). The technical building requirements can also be mapped only to a certain extent in checking software since the architecture model does not yet carry all the necessary information and the content of the legal material further cannot be mapped mathematically in many areas. Section 4.3.10 discusses the current status and a future procedure in more detail.

All checking criteria can be supported in the checking software by filtering the available elements. In Austria, ÖNORM A 6241-2, Annex A (normative) can be used for the classification into element classes. This divides the various elements logically regarding their use. This allows a logical check within this classification and of element classes against each other to be carried out.

This is particularly helpful for the QCC when a collision check of primary construction elements is carried out against element class I of the MEP. In this way, missing or defective openings in primary construction elements can only be checked in a filtered manner, without having to pay attention to openings in finishing elements, which are not required in the early planning phases. The following figure shows the different element classes:



4.3.5 Conducting the coordination meetings

The results of a model check are always communicated. This is usually done in the coordination meetings defined by the coordination plan and the data delivery plan. A coordination meeting is chaired by the *BGK* team, and the various *BFK* teams and the *BPS* team participate. This ensures that information regarding the planning status and pending work is communicated to the planners and BIM designer (by the *BFK* team) and to the client (by the *BPS* team).

A coordination meeting takes place directly after a *BGK* model check. The *BGK* team presents the check results within the checking software and communicates them to the responsible *BFK* teams. It is defined, among other things,

- by when the defects must be corrected,
- who takes primary responsibility for remediation if multiple domains are involved,
- which goals must be achieved by the next coordination meeting, and
- what priorities are to be set for correcting deficiencies and the upcoming reconciliation.

The *BFK* teams can also present their internal domain model check results in the coordination meeting and specify and agree on requirements for the other domain models. The *BGK* team records the minutes of the coordination meeting and then forwards the minutes and the associated check reports to the participants via the collaboration and communication platform.

BGK and *BFK* check reports are composed of the individual BCFs for the defects and the associated PDF check report:

- composition of the BCF audit report:
  The check report in BCF format contains the listing of the check results from the BIM application used for quality assurance. The elements associated with a check result must be assigned to the BCF comment based on their GUID. Any communication between project participants regarding the check result must be continued on the basis of the BCF comment in order to maintain traceability.
- composition of the PDF check report:
  The check report in PDF format contains the listing of the check results from the BIM application used for quality assurance and an evaluation of the check results based on the defined classification scheme.

The *BGK* classification scheme supports the classification of the check results into the current stage of development. This makes it possible to show to all participants and the client to what extent the individual domain models and the coordinated (federated) overall model meet the requirements. A classification scheme shows the degree (percentage) to which the model data are correct – i.e., have »passed« the check. There can also be the indication »not passed« if the model data are not yet available in an appropriate format.

If the model data (as a whole or in relation to individual domain models) is not yet available in an appropriate format, the *BGK* team can decide whether this issue can be dealt with in the next coordination meeting or whether certain deficiencies must be rectified before continuing. This procedure applies to the medium reconciliation cases within a project phase.

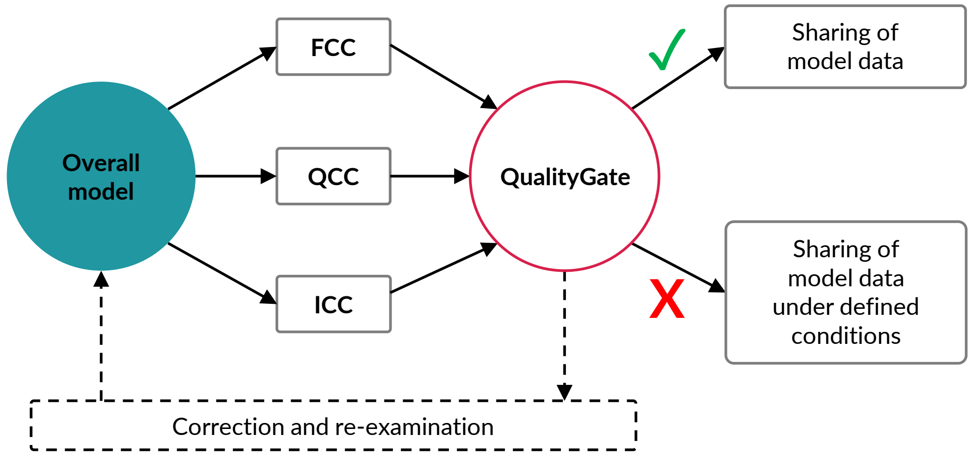
At the end of a project phase or milestone (big reconciliation case), QualityGates are used as a benchmark for passing to the next project phase. The model data can only be passed to the next planning step if the QualityGates have been passed in full or if binding conditions have been met for the elimination of defects.

Achieving a QualityGate does not necessarily mean passing all checks 100%. For example, a completely (100%) collision-free overall model, or individual domain models, can usually only be achieved with great effort. Smaller collisions can be accepted if this results in that

- there are no relevant deviations in the quantity and mass calculations,
- the execution is not endangered, and
- the elimination of these collisions means a considerable additional effort in the modelling.

This contrasts with a complete (100%) LOI in the domain models at the end of a phase or milestone. A complete LOI in the domain models is necessary to be able to continue to use the model data in a secure form in subsequent project phases.

A classification is defined in the BEP, which check queries must be passed 100% or with correspondingly lower percentages for a QualityGate.



Several steps need to be taken for a coordination meeting to be successful. If this is the first coordination meeting, the following must be ensured beforehand:

- *BPS*: CDE has been set up, and the organisational units have been trained or have been given access
- *BGK*: The BEP contains all necessary specifications (coordination plan)

For the first and all subsequent coordination meetings, the *BFK* should carry out the following steps:

- testing of the own domain model in the testing software (FCC > QCC > ICC),
- preparation of the test report (.bcf and .pdf), and
- timely provision of the checked domain model, the check reports and, if required, the planning documents derived from the domain model on the CDE. Informing the *BGK* team about the provision.

The *BGK* team now has access to all relevant data and can carry out interdisciplinary coordination for the coordination meeting:

- collection of the domain models from the CDE and merging in the coordination model (in the checking software):
  Note: if this is not the first coordination meeting, the models are updated in the coordination model;
- checking the individual domain models for conformity (positional correctness) with each other;
- execution of the test routines (FCC > QCC > ICC):
  The test must be carried out for each domain model; then the domain models are tested against each other (interdisciplinary); and
- part of the audit is the review of the results and the creation of issues for the identified problems, including the assignment of responsibilities and priorities.

The timeframe for reviewing the domain models may vary depending on the project size, the timeframe/phase of the project, or the type of project (new construction, conversion/refurbishment). This should be considered when preparing the coordination plan. After the *BGK* has reviewed the domain models, the scheduled coordination meeting is held:

- *BGK*: chair the coordination meeting and present the results. Depending on the scope of the issues, the *BGK* can address all problems or limit itself to the most urgent topics. However, all issues are submitted afterwards.
- *BFK*: possibility of direct comments on issues. If issues raised by the *BGK* team have already been solved according to the responsible *BFK*, the issue still remains until it can be verified in the next coordination meeting.
- *BGK*: the allocation of responsibilities or priorities already made can be adjusted collaboratively.
- *BGK*: conclusion of the coordination meeting and subsequent provision of the audit report (.bcf and .pdf). Reporting to the *BPS* team.

The coordination meeting is the heart of integral collaboration. All relevant organisational units participate and contribute. On a case-by-case basis, new findings may arise during the project that requires an adaptation of the BEP. This is done by the *BGK* and must be approved by the *BPS*.

Examples of typical issues in collaboration, model checking, and issue creation:

- Why do both architectural and structural elements carry the characteristic information on load-bearing elements (LoadBearing is true/false)?
  - To be able to compare the architecture model with that of structural engineering (model comparison check), the architecture model must be reduced to the load-bearing elements in the check. Non-load-bearing elements of the domain model of architecture are not considered in the comparison.

  - The architecture must provide the structural planning with a separate, reduced domain model for collaboration, which only contains the load-bearing elements. Model elements that are not load-bearing or documentation elements (spaces = IfcSpace) are not relevant for structural planning and its work to be carried out. In the modelling colloquium, an independent transfer configuration is defined for this purpose.
- What must be considered in phase-appropriate model testing?
  - As the project phases progress, the sharpness of the collision check should be adjusted. I.e., the tolerance values for overlaps are readjusted in the checking rules with each new project phase. For example, the overlap of primary components (see Section 4.3.4) can be checked with a tolerance of 2 cm in the preliminary design and 0.5 cm in the submission project phase.
  - Care should be taken that only model elements that are relevant in the project phase are tested. In the design phase of the project, the interdisciplinary testing of building services elements against architectural elements, e.g., on the load-bearing architectural elements (primary building elements), but not against finishing elements (= element class 1), makes sense. It also makes sense to restrict the building services elements to the cable routing and central units. The rooms of the architectural model are checked against the model elements of the building services in each project phase to ensure the minimum clearances. Checking any outlets that have already been modelled (IfcOutlet) would be premature in the design phase of the project, as the architectural elements (e.g., walls, suspended ceilings) can still change.
- Who is responsible for interdisciplinary issues?
  - If the collision checks between the domain model of the architecture and the domain model of the building services reveal deficiencies (= collisions), the *BGK* team must ensure that a logical coordination sequence is specified. If, e.g., cable routes collide with load-bearing walls, a breakthrough coordination should be requested. The assignment is therefore made to the building services team, which must provide the architecture team with the construction details for the coordination of the breakthroughs. If the position of the openings is correct for the architecture, the building details are approved, and the openings are incorporated in the architectural model. As a result, the previously found collisions should no longer exist at the next coordination meeting. In the case of breakthroughs, it should also be mentioned that these must, of course, also be checked, approved, and incorporated by the structural planning department. The assignment of such issues by the *BGK* team is therefore made to the building services team as the responsible body, but the architecture and structural planning are also listed in the BCF commentary for information purposes.

4.3.6 Performing the data transfer

The execution of a data transfer is a use case that occurs at the end of a project phase or milestone. It concerns the final planning results of a project phase that are to be transferred. These are to be provided by the respective *BFK* team on the collaboration and communication platform. For all data transfers, the naming and scope requirements as defined in the BEP apply.

For the transfer of the domain models (IFC file), the following applies:

- compliance with the specification regarding the degree of elaboration of the domain models;
- compliance with these requirements must be ensured before the data is made available on the collaboration platform; approval is given by the *BGK* team:
  - all aspects to be checked must provide corresponding positive results; this is to be understood as a corresponding QualityGate,
  - a further examination of the content of the functional project objectives must be carried out separately, and
  - compliance with the specifications must be demonstrated by means of an attached check report in accordance with the specification;
- supplementary information or in-depth information (e.g., detailed plans) are placed in the domain model by the designer by using BCF comments; and
- all planning documents are derived from the respective domain model.

For the transfer of the planning documents (DWG/DXF), the following applies:

- they must be created according to the normative specification and
- plans (DWG/DXF) must correspond to the checked and approved status of the domain model (IFC file). 2D information that is only contained in the planning documents (e.g., dimensions) must not contradict the information in the domain model.

For the transfer of the plans (PDF), the following applies:

- plans (PDF file) must correspond to the checked and approved status of the domain model (IFC). 2D information that is only contained in the planning documents (e.g., dimensions) must not contradict the information in the domain model.

For the transfer of native working models, the following applies:

- documentation of the modelling and CAD software products used and any extensions or program add-ons and a list of all additional special elements (for domain models as IFC files and plan documents as DWG/DXF files) must be handed over.

4.3.7 Performing model-based costing

Performing model-based costing is a use case that is encountered in various project phases.

Requirements

The cost calculation is carried out in evaluation software. Domain model data are used which have previously been checked and approved by the *BGK* team for the purpose of quantity and mass determination:

- **requirement: domain model states released according to QualityGate**.

Depending on the type of collaboration between the *BGK* team and the team performing the cost determination, different domain model data can be used. However, they are always based on the specifications of the LOG and LOI as well as the basic quantities transported in an IFC model.

- **requirement: plausibility check before and after the costing calculation**.

In some cases, the domain models carry the required information at different depths, so that a procedure for using the different domain model data must be agreed on – e.g., the quantities and masses for the shell are determined from the domain model for structural engineering or from the domain model for architecture.

- **requirement: definition of which domain model data is used for the corresponding positions.**

The requirements for the evaluation software thus include not only the ability to read and interpret IFC data correctly but also to handle multiple IFC models. The results of the quantity and mass determination are some of the things that influence the costing calculation items for a tender.

Implementation

The following specifications apply to the execution of the model-based cost determination in the evaluation software by the responsible team:

- the released domain models (IFC file) serve as the basis for data collection,
- the identification of the model content shall be performed based on the declared Ifc classes, Ifc types, material assignments, and standard features, and
- masses and quantities must be derived from the model geometry; deviations are permitted only in consultation with the *BPS* team.

4.3.8 Updating the project specifications in the course of planning

The BEP set of rules is a living document. It is created at the beginning of the project, based on the specifications and requirements of project-specific EIR. However, in order to remain applicable for a project over its entire course, the BEP must be able to reflect developments in the project and constantly evolve.

As the creating role, the *BGK* team is responsible for updating the BEP. Changes in the BEP must always be coordinated with the *BPS* team in order to continue to fulfill the specifications and the requirements of the client.

Updates of the BEP **can be due to**

- extended requirements from the client,
- extended requirements from the contractor,

- expanded or adapted procedures,
- expanded knowledge, and
- changing specifications at the level of
  - project participants,
  - interfaces,
  - transfer configurations, and
  - use cases.

Modifications of the BEP must also always be sent to the project-related EIR, although an update of the EIR by the *BPL* team is not mandatory. However, new information discovered throughout the course of the project should be examined to determine whether they should be incorporated into the project-independent corporate standard EIR so that the new findings can be considered in future projects. The task of continuing to develop the project-independent corporate standard EIR lies with the *BPL* team, which is supported by the *BPS* team.

4.3.9 Updating the model data

In the continuous updating of the domain models, the obligation to plan integrally and to comply with the specifications applies to the

- collaboration and communication platform,
- interfaces,
- codes and standards,
- authorship and responsibility of the domain model content,
- mandatory coordination with other domain models,
- internal quality assurance,
- transfer configurations,
- modelling, and
- degree of elaboration.

In the event of a change of project participants, care must be taken to transfer the planning data, including the domain model data, in such a way that the new responsible unit can take over the data without loss.

4.3.10 Carrying out the model-based permit process

The openBIM model as the central location of building data and information has potential for the entire life cycle of a building. However, the building submission currently plays hardly any role in the BIM project cycle. Rather, the currently required submission documentation represents an additional effort for BIM planners, since conventional 2D plans have to be generated from the models and enriched in a specified manner.

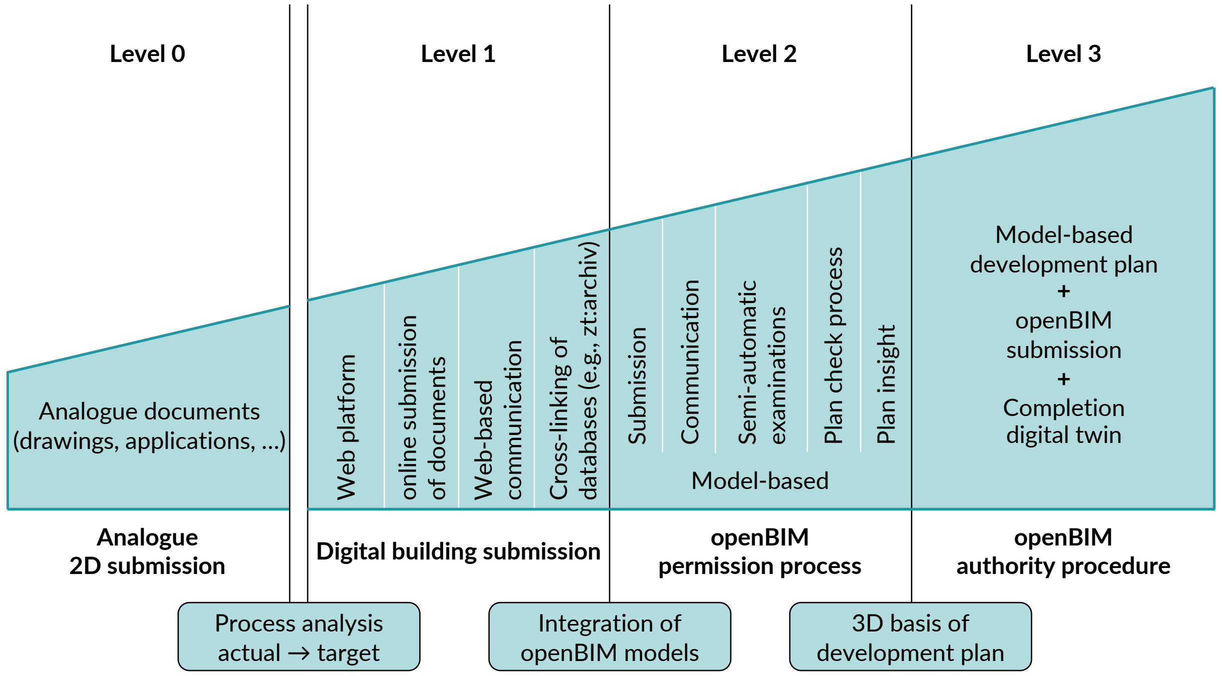
The openBIM permit process offers a wide range of advantages not only for the authorities but also for the entire construction industry. These are primarily the increased transparency in the execution of the procedure and the increased comprehensibility of the decisions. A detailed analysis reveals the following advantages:

- The elimination of time-consuming routine inspections by the building authority means that the capacities freed up can be concentrated on the more legally complex inspection points. This accelerates and improves the quality of the approval process.
- A BIM approval procedure can only be carried out by means of an open File format, which strongly promotes the use of openBIM. This in turn strengthens smaller and medium-sized planning offices, which can continue to utilise their modelling software without having to purchase new software for new projects.
- The planning offices receive an automatic basic quality check that can be carried out at any time by means of a construction engineering BIM check (even before the building application is submitted). This reduces the effort for official channels, improves the building application model (BAM) quality, and, as a result, accelerates the building application process. In practice, planning offices could also use the check for staff training purposes.
- The authority procedure exhibits greater transparency.
- The biggest advantage for the construction industry lies in the LOG and LOI requirements: The exchange information requirements (EIR) of projects and the associated LOG and LOI requirements vary widely. The openBIM approval process creates a project-independent general standard – a kind of quality seal – as the approved BIM model must meet clear LOG and LOI requirements. The building applicant and other parties (e.g., contractors for costing) can therefore better implement the BIM model in their BIM applications, since the information is already stored and checked in a standardised way

The openBIM approval process will therefore make a significant contribution to making better and more far-reaching use of the advantages of BIM and to supporting more planning offices before and during the building application process. Building authorities and administrations alike will benefit from the standards required for openBIM submissions. Thus, planning quality in BIM will improve further and BIM will be used more frequently.

As a result of these benefits, more and more projects are now addressing the topic of digital transformation of the building authority or the approval process. The city of Vienna, Austria, e.g., has developed a platform for digital building submission. On this platform, building applicants/planners can access information, look for specific procedure types, and upload submission documents. However, due to legal framework conditions, a set of drawings must currently still be submitted to the authority in printed form. In the EU-funded research project BRISE-Vienna, the City of Vienna is going one step further by trying to integrate the approval process into the BIM project cycle.

Based on the research projects Digital Building Submission and BRISE-Vienna, the maturity model for approval procedures shown in the following figure was developed in accordance with ISO 19650. The maturity level of the municipalities ranges from level 0 to level 3. The current starting point for many municipalities is level 0. Submission documents are submitted in printed form and manually reviewed, entered in a digital platform, and checked by the respective expert. Communication takes place via e-mail or by letter. Reaching maturity level 1 requires an as-is process analysis followed by a to-be process evaluation. This target/actual process evaluation defines the necessary technical (collaboration web platform) and legal developments. This step is crucial, as it does not make sense to only digitise existing processes without making other changes. The use of new digital tools (BIM, drones, artificial intelligence, augmented reality, etc.) in government procedures requires the rethinking of traditional processes. Therefore, it is necessary to record and analyse the actual processes and then digitally adapt them according to the technology available. Maturity level 2 is achieved through model-based submission (building application model) and partially automated review. The legal basis (zoning plan and development plan) is still available as 2D plans. In maturity level 3, the permitted building is shown in three dimensions, which means that considerably more legal questions relating to neighboring properties can be checked automatically.



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4.3.11 Performing the check run of the transfer to the operator's CAFM system

The establishment of operations management – especially on the basis of model-based information from BIM projects – represents a novel situation for many FM departments that requires intensive preparation. For this reason, a check run is often carried out during the course of the project to connect the CAFM system of the future operator. This takes place at the latest at the end of the design phase of the project, when fully coordinated and sufficiently detailed model content is available for the first time.

In this case, it is necessary to adjust the intended scope of the data delivery in the data delivery plan accordingly during the creation of the BEP (see Section 4.2.8). There are various specifications that are preferred, and they are usually only to be provided with the final documentation. Such specifications include tabular model evaluations which transfer model content to the CAFM system. In addition, the transfer of the supplementary documentation and its link with the model content are tested.

The objective of the trial run for connecting the CAFM system is to prepare the operators and their CAFM systems at an early stage. If problems are identified during the check run, there is sufficient time to solve them. At this point, any problems with the model content or its specifications in the BEP can also be solved. The trial run for the connection of the CAFM system is executed under the direction of the *BPS* team, which controls the activities of the *BGK* team and their respective *BFK* teams and at the same time maintains contact with the FM department of the operator.

4.4 Tendering and awarding

Life cycle phases »Tendering« and »Awarding« serve to identify and commission a contractor for the construction work (Construction contractor). This is based on the principles developed in life cycle phase »Planning«.

Only the award procedure is handled in this life cycle phase. BIM model data can be used to support this (collection of masses and quantities, clarification of the planning intention). However, they are only a supplement to the actual core component of the tender: the bill of quantities. The following use cases describe a currently (as of 2023) common scenario of BIM-supported tendering and awarding. In this case, the *planning contractor* determines the masses and quantities of most of the service items based on the domain models; however, some parts of the bill of quantities are still handled conventionally because they are not included in the model (e.g., construction site equipment). In addition, the collaboration platform serves as the basis for processing the procedure, and model data is made available to the bidders for review. The project phase concludes with the commissioning of a *construction contractor* and a further BIM procedure that is mutually agreed in the BEP.

4.4.1 Identifying and compiling project-related requirements

In close coordination with the client, the *planning contractor* compiles the project-related requirements for awarding the construction contract and the correspondingly planned data transfers from the *construction contractor* to the *planning contractor*. Any company-wide, cross-project specifications serve as the basis. The result is a GU-EIR (general contractor EIR). As part of the invitation to tender, this describes the requirements for structured data transfer from the executing contractor to the *planning contractor* during construction.

Institutional clients use the predefined company-wide AIR or EIR (across projects) as a basis. These two documents declare the general framework requirements regarding basic uniform procedure implementation and data transfers (of product information from the *construction contractor* to the *planning contractor* in particular) across all projects.

In the first step, the *planning contractor* determines the most suitable strategy for the project. The project complexity/size, the assessment of the capabilities of the potential bidders, and the corresponding objectives of the client are decisive criteria. In the second step, the *planning contractor* summarises these requirements on a project-specific basis. Thus, they are available as the basis for the subsequent compilation of the GC-EIR.

The GC-EIR provide bidders with an overview of

- general project-related BIM processing,
- their tasks related to this, and
- the resulting responsibilities during construction.

This enables the bidders to precisely estimate the required effort to participate in the BIM project and include this in their bid.

4.4.2 Preparing the model basis

Now the *planning contractor* team prepares the project-related model bases

- to provide a basis for the model-based collection of masses and quantities (support of the creation of the cost calculation) and
- to be prepared as an supplement to the invitation to tender (clarification of the planning intention).

Typically, the existing BEP defines the required workflows and specifications for model export, model checking, and for determining masses and quantities. The result is a reviewed and approved domain model on the collaborative platform in accordance with the corresponding BEP specifications.

4.4.3 Preparing the collaboration platform

The *BPS* team is usually responsible for the collaboration platform and, hence, also prepares it. Thus, it creates the following tasks for the execution of the tender and award:

- set up any predefined processes (workflows),
- customise the appropriate authorisation structures to include bidders,
- set up user access for bidders,
- setup the components to carry out the tendering and awarding process, and
- perform a check run to evaluate the intended functionality.

The result is a collaboration platform that is set up in accordance with the corresponding specifications of the BEP for the tender processes. The range of functions required to carry out the tendering and awarding process is not always part of the collaboration platform. In recent years, various web applications have appeared on the market that focus specifically on the execution of this use case.

4.4.4 Preparing the tender documents

In this step, the *planning contractor* consolidates all necessary documents. In the context of BIM-supported tendering and awarding, the following work steps are relevant:

- final determination of the masses and quantities for the most important service items from the checked and approved domain models,
- final reconciliation of the GC-EIR to describe the requirements of a structured data transfer during construction from the *construction contractor* to the *planning contractor*, and
- coordination of any best bidder criteria with reference to the required capabilities for the participation of the *construction contractor* in the BIM project, e.g., for the structured handover of product information.

The results are finalised and coordinated documents for the tender, in accordance with the relevant specifications of the BEP. The criteria for the best bidder consider project-related aspects as well as the current market situation.

4.4.5 Carrying out the tendering and awarding

The *planning contractor* carries out the tendering and awarding in close collaboration with the client to determine the best bidder for the execution of the construction. In the context of BIM-supported tendering and awarding, the following steps are taken:

- announcement of the compiled invitation to tender and summoning of the intended bidders, if any;
- bidders register their interest and get access to the collaboration platform (or the separate *AVA* platform);
- bidders receive all relevant tender documents on the collaboration platform (or the separate *AVA* platform) – in particular:
    - the bill of quantities,
    - the relevant domain models (ideally barrier-free by means of integrated viewer functionality and a visualised link to the service specifications), and
    - the GC-EIR to describe the general project-related handling of BIM, the related tasks of the *construction contractor*, and his resulting responsibilities during construction;
- bidders prepare bids within the defined time period and post the result on the collaboration platform (or the separate *AVA* platform);
- in close collaboration with the client, the *planning contractor* analyzes the bids and creates a price comparison list for the qualified comparison of the bidder data – this serves as a basis for preparing the negotiations;
- conducting negotiations or renegotiations with the best bidder or other bidders – any reworking of the bids is handled, reviewed, and analyzed via the collaboration platform (or the separate *AVA* platform), and
- awarding of the contract. In the event of unsuccessful negotiations, amending of the invitation to tender with amended criteria or other required services.

4.4.6 Joint development of the project strategy for the construction

Once the contract has been awarded, the *BPL* and *BPS* teams develop the project strategy for construction together with the future contractor. For this purpose, the *BPL* and *BPS* teams present the complete scope of the developed fundamentals (regulations, service specifications, GC-EIR) to the future *construction contractor* and explain the details. This step is necessary to mutually agree to all contexts and requirements and thus establish a uniform view of the project requirements for implementation in the future project team. This activity takes place in the first colloquium. At this time, the *construction contractor* also announces how the responsible persons for data transfers or required BIM organisational units are determined.

Subsequently, the BEP colloquium takes place (see Section 4.2.8). In this colloquium, the *construction contractor* specifies how and in which steps the client's specifications (from the GC-EIR) will be implemented. The *BPS* team moderates this process; the associated content is received from the *construction contractor*. The results flow into the updated BEP. The result of this activity is a mutually agreed procedure laid down in the BEP. This is aligned with the actual capabilities of the personnel of the Construction contractor working on the project and runs within the framework of the general specification – the predefined company-wide AIR or EIR (cross-project).

The *construction contractor* can participate in the BIM project from initial construction preparation or work and assembly planning through the entire construction to the handover of the building. The *construction contractor* can, therefore, use existing BIM information and provide the required information in a structured manner. Collaboration within the entire project team takes place without media discontinuity.

The future authorship of the domain models is also defined during this phase. If there is a change of authorship from the *planning contractor* to the construction team, the activities described below will become considerably more important.

4.4.7 Regulating the project model (PIM) by means of BIM colloquia

The BEP colloquium is followed by a modelling colloquium (see Section 4.2.9) if the *construction contractor* is planning to adopt and update domain models (e.g., MEP).

This activity is carried out by the *BPS* team and serves to evaluate the specifications for model-based project implementation (BEP) and to ensure that the *construction contractor* can carry out the planned tasks for model updating in the required quality. The *construction contractor* must demonstrate that it can successfully handle relevant use cases and work to the specifications from the BEP based on a partial model. This includes the native transfer of the model data to the contractor's BIM software application.

It is mandatory that these steps be completed prior to the start of construction to prevent BIM setup and construction from becoming intermingled.

4.5 Construction

Life cycle phase »Construction« serves to carry out the construction of the building project by the *construction contractor* determined in the previous life cycle phase. This is based on the fundamentals developed in life cycle phase »Planning«.

4.5.1 Carrying out model-based construction scheduling

The implementation of 4D BIM planning focuses mainly on the documentation of the project and serves to map the construction process that has taken place. For this purpose, the necessary properties are coordinated with the *construction contractor* and entered and updated in the model by the respective domains. This allows for the verification of the interim invoices for trades mapped in the model.

4.5.2 Carrying out the work and assembly planning

At the start of construction, the contractor carries out the work and assembly planning on the basis of the existing execution planning information and agrees to the use of the intended building products. Conventionally, the execution of the work and assembly planning is carried out by means of 2D-based detailed drawings which are subsequently linked to the model to clearly define their affiliation. The interaction with the model of the *planning contractor* as well as the corresponding intended responsibilities are defined in the BEP. The result is a work and assembly plan that describes in detail how the construction is to be carried out with the intended construction products by all the trades of the *construction contractor*.

In general, it must be ensured in advance – during the tendering and awarding process – by means of appropriately formulated restrictions in the tender documents that the framework specifications of the planning model are (essentially) not exceeded in the work and assembly planning. The fully coordinated and optimised quality of the planning model must be maintained. In the case of rescheduling, it must be ensured that this generates overall added value. In addition, the effort required to update the model must be considered. The determination of authorship for the domain models is an essential aspect while determining the strategy for construction. Here, mixed strategies can have a favorable effect – e.g., the architecture model remains with the *planning contractor*, while the building services model passes to the *construction contractor*. However, the effort required to transfer the model must be considered. Decisions to this effect must always compare the total costs with the achievable added value. Savings in construction costs that can be achieved in the short term must not cancel out savings in operation that can be achieved in the long term that were determined while planning.

The construction work and assembly planning is carried out based on the following rules:

- access to the collaboration platform shall be given to the *construction contractor*,

- the execution and detailed design of the *planning contractor* shall be made available on the collaboration platform,
- the detailed planning performed by the *planning contractor* shall be linked to the respective construction elements of the digital models (by means of BCF comments or a BCF file),
- the contractor shall make the documents corresponding to the work and assembly planning in digital form available on the collaboration platform, and
- the release of the work and assembly planning information shall be carried out digitally on the collaboration platform by the *planning contractor*.

In addition, the following applies:

- If a revision of the digital models of the *planning contractor* is made necessary due to incorrect or incomplete information provided by the *construction contractor*, the respective expenses of the *planning contractor* shall be recorded (for each individual domain planner or the whole domain) and deducted from the *construction contractor*'s fee.
- All project changes, regardless of the reason for the change, are to be transmitted to the *planning contractor* to be inserted into the digital models after approval by the *ÖBA*. The changes are to be transmitted regularly, with the transfer intervals to be determined jointly by the *planning contractor* and the *ÖBA*. The changes are to be transmitted as DWG plans. All elevation data for components shall be noted in the DWG plans. The level to which the information refers (top edge, middle, bottom edge) shall also be defined.

Implementation

The following specifications apply to the execution of work planning and coordinated execution planning:

- The *planning contractor* provides execution and detailed planning information (consisting of digital models, plans, details) on the collaboration platform.
- Based on this information, the *construction contractor* carries out the conventional work and assembly planning (workshop and assembly plans including the corresponding execution details, selection of products, etc.) with including documents.
- The *construction contractor* provides the associated documents on the collaboration platform.
- The *construction contractor* links the detailed planning information (from work and assembly planning) on the collaboration platform with the digital models of the *planning contractor* by means of BCF comments or a BCF file.
- The *BFK* team responsible for the respective domain models compares the execution and detailed planning information with the *construction contractor* and assembly planning information and identifies deviations.
- If deviations (position, dimension, specification) are identified, effects on the existing planning data must be checked by the *planning contractor*.
- The *planning contractor* coordinates with the *ÖBA* and the *construction contractor* on how to proceed with any changes. If necessary, the *construction contractor* modifies the work and assembly planning documents.

- The *BFK* team responsible for the respective domain model checks the documents provided for the *construction contractor* and assembly planning and approves them.

Result

The following results are to be produced in the course of the work planning and coordinated execution planning:

- approved work and assembly planning of the *construction contractor*, which has been integrated in the execution and detailed planning of the *planning contractor*,
- approved work and assembly planning of the *construction contractor*, which can be used as the basis for construction,
- all documents of the *construction contractor* and assembly planning are available in digital form on the collaboration platform, and
- the detailed planning of the *construction contractor* is linked to the respective construction elements in the digital models of the *planning contractor* by means of BCF.

4.5.3 Carrying out the asBuilt documentation during construction

The surveyors and the authors responsible for the domain models carry out the asBuilt documentation during construction. Hence, they ensure that the construction conforms to the planning specification (at the level of work and assembly planning). Laser scanners are used to record the respective construction stages. The resulting point clouds are automatically compared with the domain models. Any deviations can be identified and coordinated, and the result can be documented in the model. The relevant specifications for implementation and the associated responsibilities are defined in the BEP. The result is the complete documentation of the asBuilt status in the form of updated domain models.

Requirements

Model-based asBuilt documentation is performed according to the this rules:

- Access to the collaboration platform must be granted to the surveying team.
- The surveying team will receive training on the use of the collaboration platform as needed.
- The domain models represent the data basis (target state).
- The recording of the building condition (actual condition) is to be carried out by qualified personnel of the surveying team description by means of laser scanners according to the following description.
- *ÖBA* reports completion dates to the surveying team in a timely manner.
- The contractor shall ensure the basic visual accessibility of the completed services on the completion date.
- The recording of the construction condition (actual condition) is carried out in the following phases of construction. The exact times of the execution are to be determined by the *ÖBA* in collaboration with the *construction contractor*:
  - completion of shell (floor by floor),
  - completion of MEP / collecting lines (basement),

  - completion of finishing / dry wall construction (floor-by-floor, single-sided planked walls),
  - completion of MEP-V (floor by floor, main lines/central offices / distributors),
  - completion of MEP-E / I (floor by floor, main lines / central offices / distributors),
  - completion of MEP-S (floor by floor, main lines / central offices / distributors), and
  - completion of building and exterior (as a whole).
- Provision of the results of the survey to general planner and *ÖBA* is to be carried out via the collaboration platform.

Implementation
The following guidelines apply to the implementation of asBuilt documentation:
- The *construction contractor* notifies the *ÖBA* of upcoming completion dates.
- The contractor shall coordinate the dates for the recording of the construction status (actual status) with the *ÖBA*.
- *ÖBA* reports the surveying dates for the recording of the condition of the construction (actual condition).
- The *construction contractor* prepares the completed section (floor by floor) for the recording time slot and ensures visual accessibility (e.g., material storage, scaffolding, etc.).
- The surveying team performs the recording of the state of construction (actual state) on the scheduled date.
- The surveying team reports completion of the recording of the construction condition (actual condition) to the *construction contractor* and the *ÖBA*.
- The surveying team provides the results to the *BGK* team.
- The *BGK* team compares the point cloud (actual condition) with digital models (target condition) and, if necessary, identifies deviations of positions and dimensions beyond the contractually specified construction tolerance (according to the bill of quantities).
- In case of deviations, the *ÖBA* will be notified.
- The *ÖBA* in coordination with the client decides between the following two options:
  - adjustment of the deviations by the *construction contractor* (deconstruction or new construction) or
  - prompt adjustment of the execution and detailed planning (consisting of digital models, plans, if necessary, also details) by the responsible author of the respective domain model at the expense of the author.

Result
The following results are to be produced during the creation of the asBuilt documentation:
- documentation of the respective phases of construction by means of the survey data (according to the specification for data of the existing building) and

- documentation of the state of construction by means of updates to the execution and detailed design (consisting of domain models, plans, associated final details).

4.5.4 Performing model-based product documentation
The *construction contractor* prepares the model-based product documentation in which the products installed are documented for commissioning and subsequent operational management. The domain models updated during the creation of the asBuilt documentation serve as the basis. Based on these models, construction product specifications are collected and randomly checked for compliance with the built construction. For the product specifications thus evaluated in the model, the *construction contractor* enters the required product features for operational management (LOI500 for maintenance, checking, warranty, etc.) in the model and collects the associated documents (technical approvals, instructions, etc.) in a structured manner. These documents are stored in a structured manner on the collaboration platform and linked to the model. The relevant specifications for implementation and the associated responsibilities are defined in the BEP.

The result is a complete product documentation of the asBuilt state contained in the updated domain models (LOI500) as well as the linked documents.

Implementation
The following guidelines apply to the implementation of the final documentation:
- The *BPS* team provides templates (which may not be changed structurally by the *construction contractor*) for the transfer of product information (tables according to the Austrian standard ÖNORM A 7010-6, Annex B). The content of the product information tables refers to elements (and their unique number: GUID) from the domain models.
- The contractor shall provide the product proposal (based on the planner's template) in the course of work and assembly planning.
- The client / planning contractor / the *ÖBA* check equivalence and issue product proposal for approval if necessary.
- The contractor shall send product information in a structured form (based on templates for the transfer of product information provided by the *BPS* team) to the *planning contractor* (as an Excel spreadsheet or via a database interface).
- The *ÖBA* verifies products in the completed structure on a selective basis and issues approval if necessary.
- The respective responsible author transfers the product information to her/his domain model.

Result
The following results are to be produced during product documentation:
- domain models updated to LOI500 (with details of maintenance, checking, warranty, etc.) and
- storage of the associated documents (technical approvals, instructions, etc.) collected in a structured manner and linked to the model.

4.5.5 Compiling and handing over of construction documentation

This activity is carried out by the responsible authors of the domain models as soon as construction is complete and serves to check and merge the steps executed during the creation of the asBuilt documentation and product documentation carried out in the previous activities. The relevant specifications for the implementation and the associated responsibilities are defined in the BEP.

The result is complete, verified documentation of the asBuilt structure contained in the updated domain models and technical documentation, suitable for handover to management. The following applies: The handover of the final documentation for the construction handover must be complete and free of errors. The following applies when the associated domain models (IFC file) are provided:

- The specification regarding the degree of elaboration of the domain models must be complied with.
- The complete and error-free compliance with the specifications regarding the degree of elaboration of the domain models must be proven by means of a check report.
- All plan documents provided in addition to the model shall be derived from the respective domain models.
- All supplementary information or more detailed information (e.g., detailed plans) is placed in the domain model by the designer using BCF comments.

The following information is to be handed over:

- summary file directory,
- documentation of the modelling and CAD software products used, any extensions or program add-ons, and a list of all additional special elements (it must be possible to reproduce the working environment),
- the domain model architecture (native and as an IFC file) with all domain models as an IFC reference,
- the remaining domain models (native and as an IFC file),
- the last valid positive check reports (as PDF and BCF files),
- the room and plant book (as an XLS file),
- the SAP component list for all care/maintenance/inspection-relevant equipment (as an XLS file), as well as
- the asBuilt documentation with point cloud (E57file) and panoramic images (TIFF files).

Result

The following results are to be produced during the creation of the final documentation:

- documentation of the construction condition by means of updated execution and detail planning information (consisting of digital models, plans, details) including all relevant product information (in Austria: according to ÖNORM A 7010-6, Annex B).

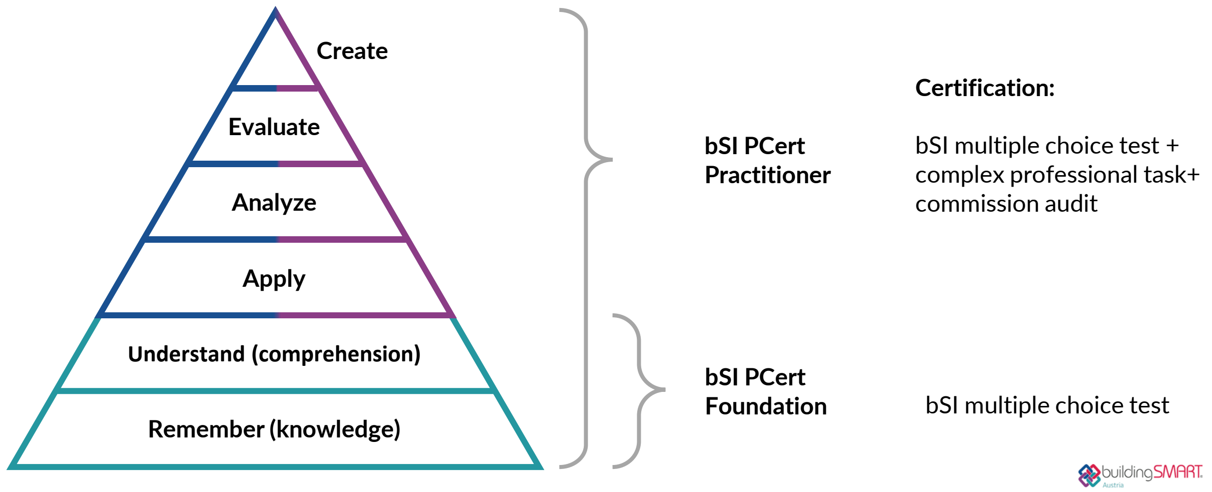
The client receives a complete documentation of the structure. Based on this, in Austria the future operator can link its technical and commercial management in accordance with ÖNORM A 7010-6.

Appendix

A bSAT BIMcert Professional Certification Curriculum

BIMcert PCert Training und Certification

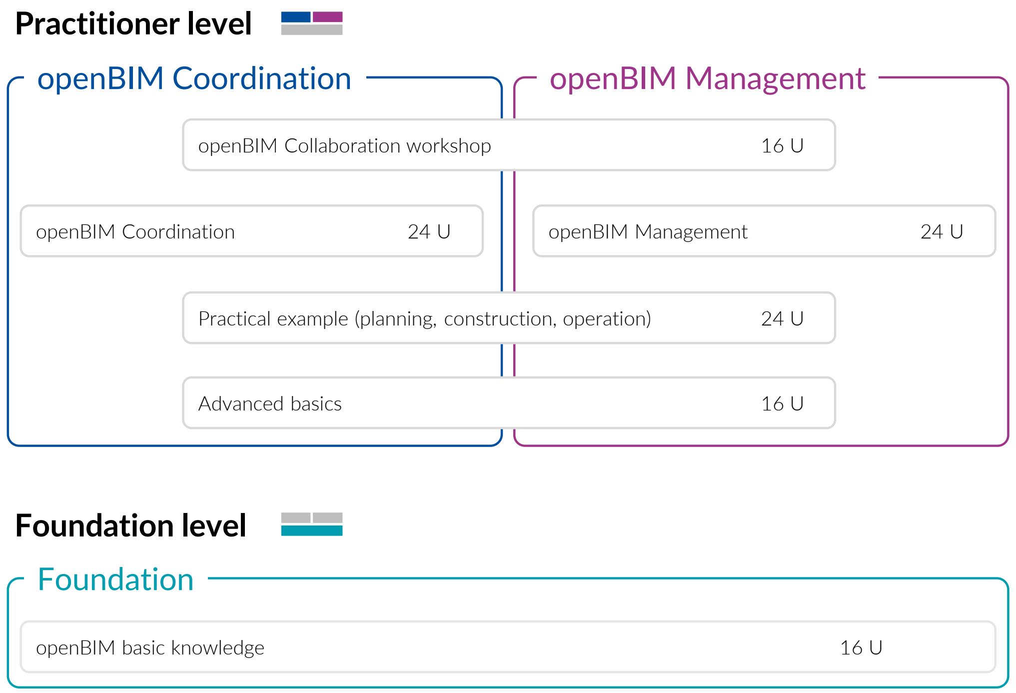
The certification model is based on the certification levels of the buildingSMART »Professional Certification« program. The basic certification is the buildingSMART International »Professional Certification – Foundation« and includes the related content. This certification is the basis for all other certifications. Therefore, successful completion of the corresponding certification exam is required to participate in the advanced qualification training. This ensures that everyone speaks the »same language« and uses the same terminology. According to the specifications of buildingSMART International, a »Professional Certification – Foundation« course is mandatory to be allowed to take the certification exam. After that, the other certifications can be pursued. These are mainly intended for practitioners.



The certification model provides a separate certification exam for each qualification. The next figure shows the qualification and certification model as buildingSMART Austria will use it as BIMcert PCert.

This curriculum presents a curriculum optimised for bSAT, including module and topic block descriptions. These include the content and competences to be taught. The qualification levels are based on the buildingSMART International Professional Certification Program. Thus, in addition to the Professional Foundation qualification, this curriculum provides two qualifications for the Professional Practitioner level: openBIM Coordination and openBIM Management. The certifications are called:

- »buildingSMART Certified Professional (bSCP) – Practitioner openBIM Coordination« und
- »buildingSMART Certified Professional (bSCP) – Practitioner openBIM Management«.



The buildingSMART Certified Professional certification is aimed at practitioners in the field of openBIM. This certification shows that the certified person is an expert in the area and can work independently at a high level of practical relevance. This competence is at the heart of the certification.

There are currently two certification areas, openBIM Coordination and openBIM Management. Certification in these areas proves that the certified person as an expert has mastered all tasks of openBIM Coordination or openBIM Management independently and practically. BIM professionals can be certified in both openBIM Coordination and openBIM Management. The order is not prescribed and they are not interdependent.

bSAT Certified Trainer for high-quality functional training

The qualification and certification model is designed to provide high-quality functional training. To guarantee the quality of the training independent of the training partner, the trainers are subject to mandatory certification. The training partner's qualification courses must be delivered predominantly by these bSAT Certified Trainers.

A 1 Professional Certification Foundation

A 1.1 Modul openBIM Basic knowledge

This training is the foundation for the buildingSMART Professional Certification – Foundation and includes the required content. This qualification is the foundation for all further qualifications. The module contributes significantly to a common understanding of basic knowledge. The participants will get an overview of all essential terms of digitisation, openBIM basics, openBIM terms, BIM applications, openBIM organisation, openBIM project structure and BIM standardisation. Practical examples adapted to the target group or group of participants support the understanding process.

A 1.1.1 buildingSMART and digitalisation

Acquisition of competences

Upon completing this course, participants will know the basic concepts of digitisation and (open) BIM. They will have looked at digitisation in the construction industry and know where BIM fits in. They have a basic knowledge of the BIM method. Participants will have a basic knowledge of digitisation and will be able to identify the advantages, disadvantages and known problems. They know the implementation of BIM in a company. The participants will also be able to professionally classify facts and issues related to digitisation and data security.

Contents

This topic block provides a general understanding of digitalisation and buildingSMART as a pioneer for openBIM. The core content on digitalisation addresses the advantages, disadvantages, and challenges of the digital transformation of the construction industry and its implementation in the company. In addition to the benefits of the conscientious use of BIM and digital technologies by designers, clients, and operators, this includes BIM strategy and maturity as well as data security measures. On this basis, the topics of platforms and software types can then be addressed in more detail. The aims, influence, and structure of buildingSMART form further content of this topic block.

A 1.1.2 openBIM terms

Acquisition of competences

The participants know the openBIM standards developed by buildingSMART International – e.g., IFC, bSDD, IDS, MVD, BCF, LOIN, DataSheets, and UCM. They understand the process of software vendor-independent data exchange. They have basic knowledge of structural components, declaration/depth of detail (element-component-component), application areas, versions and internationally standardised views (structuring of data), and IFC expressions. They will understand IFC as the central interface of openBIM and its capabilities and limitations.

Contents

An essential basis for good domain communication is the consistent use of terms. Particularly in the area of (open)BIM, there is often a confusion of terms that leads to misunderstandings. These units focus on IFC as the central interface for data exchange in openBIM processes. To this end, the topics of structural components, declaration/structural depth, application areas, versions, views, terms, material definition and, finally, the advantages and disadvantages of IFC will be considered. This is followed by an introduction to bSDD, IDS, MVD, BCF, LOIN, DataSheets, and UCM.

A 1.1.3 BIM applications

Acquisition of competences

Upon completing this unit, participants will have a basic understanding of different software solutions, interfaces, and data structures. This includes knowledge of optimised design and execution with digital virtual building models throughout the life cycle and the different BIM levels and dimensions. Participants will know the limitations and differences to other design methods. They will be able to identify the necessary changes in design processes through the use of the openBIM method.

Contents

Participants will learn the basics of the openBIM project model. In particular, the difference to closedBIM models and the respective advantages and disadvantages will be worked out. In interaction with IFC data structure, properties and possible data structures are explained, and the linking of overall and domain models is illustrated using use cases. The necessary communication in the BIM process is shown, and responsibilities are defined. Finally, openBIM software products and their data interfaces are presented.

A 1.1.4 openBIM project implementation and standardisation

Acquisition of competences

The participants know the development stages of the openBIM method and the differences to closedBIM. They can identify the different (open) BIM roles/services and name their responsibilities. They know the BIM rules and regulations (AIR, EIR, BEP), their intended use and interdependencies. Participants can name and differentiate the respective contents and objectives. They can name the background of model-based collaboration (IDM, MVD, bSDD). The participants know the relevant international and national BIM-related standards. They know what is regulated in them and how they relate. The focus is initially on the associated information.

Contents

Participants will be introduced to the key terms in openBIM projects. They start with the LM.BIM (roles/service specification), whose necessity compared to the conventional service specifications is discussed, as well as the concrete definitions of the individual roles. Building on this, the BIM rules and regulations (AIR, EIR, BEP) are introduced and differentiated. Their contents, responsibilities and interrelationships are illustrated, including the technical guidelines (levels of detail). The next focus is on the openBIM method, the different stages of development are presented, and a clear distinction is made between the advantages and

disadvantages of openBIM compared to closedBIM. The context of the previously explained BIM regulations and relevant standards is also established.
A typical openBIM model will be presented and explained using an example model to help participants understand openBIM.

An overview of all BIM-related standards, their contents and interrelationships conclude this block of topics. After a brief outline of the historical development of IFC, bSDD and ISO 19650, the levels (LOIN), dimensions of BIM and the difference between openBIM and closedBIM in terms of data structure will be explained.

Important international standards are:

- ISO 19650-Serie,
- ISO 16739,
- ISO 12006-2,
- ISO 29841-Serie,
- ISO 23386,
- ISO 23387,
- EN 16310 und
- EN 17412.

Additional national standards to be considered in Austria are:

- ÖNORM A 2063-2,
- ÖNORM A 7010-6 und
- ÖNORM A 6241-2.

A 2 BIMcert Professional Certification Practitioner

Building on the Foundation qualification, the buildingSMART Professional Certification – Practitioner qualifications are openBIM Coordination and openBIM Management. People with previous experience in BIM application often attend this training. It is, therefore, useful to integrate this experience into the training. Participants with relevant experience and completed projects can include selected (open)BIM projects in the course. The presentations focus on a short introductory description of the project, followed by a presentation of the processes, positive developments and problems, as well as the chosen solutions. This will also lead to networking among the participants.

Modul structure:

- advanced fundamentals [C+M]
  - terms and standards
  - data structure tools and project workflow CDE
- practical example (planning, construction, operation) [C+M].
  - planning with model-based communication and collaboration
  - digital (openBIM) construction management
  - building operation (product data sheets)
- openBIM coordination [C]
  - openBIM project implementation – application of EIR to the BEP
  - openBIM coordination (quality management)
- openBIM management [M]
  - openBIM service specifications, rules and regulations
  - BEP monitoring
  - openBIM project implementation and openBIM organisation (initiation to planning)
  - openBIM project implementation and openBIM organisation (quality management)
  - Process management and process modelling
- practical workshop [C+M]
  - Collaboration workshop

All modules have a strong focus on the use of international standards:

- ISO 19650-Serie,
- ISO 16739,
- ISO 12006-2,
- ISO 29841-Serie,
- ISO 23386,
- ISO 23387,
- EN 16310 und
- EN 17412.

and the terms and standards of buildingSMART:

FC	IDS	bSDD	MVD
BCF	openCDE	UCM	DataSheets

A 2.1 Module advanced fundamentals [C+M, 16]
This module is the introduction to the Practitioner training. The focus is on a strong in-depth knowledge of the openBIM standards (co-)developed by buildingSMART International: IFC, bSDD, IDS, MVD, BCF, LOIN, openCDE, UCM, and DataSheets. The current status of standardisation will be presented to the participants.

A 2.1.1 Terms and standards
Acquisition of competences
They know the openBIM standards and terms developed by buildingSMART International: IFC, bSDD, IDS, MVD, BCF, LOIN, UCM, openCDE, and DataSheets. Participants will understand and be able to apply the standards in the context of an openBIM process. In addition, the participants will be able to explain the relationship with other standards relevant to the contract and use them in the projects.

Contents
After an in-depth look at standards, standardisation and the standardisation process (international and national), key openBIM terms and other standards relevant to the contract are explained in more detail, along with their respective application focus and how they relate to the openBIM process. The terms and standards are explained in the context of the openBIM process.

In addition to international standards, in Austria national standards should also be considered (ÖNORM): A 2063-2, A 7010-6, A 6241-2, B 1800, B 1801

A 2.1.2 Data structure tools and project workflow CDE
Acquisition of competences
Participants will understand which data structures can be mapped with which tools. They will learn about standardised data sources. They understand the advantages and disadvantages of using different forms of mapping and the capabilities of selected tools. They understand the importance of CDE for the whole life cycle and be able to apply it. The participants have an overview of which BIM software products are available on the market in which application areas and how they are suitable for the respective collaboration. They understand the importance of a Common Data Environment (CDE) as a »single version of truth« for the entire project.

Contents
It shows which data structure components can be used to achieve specific project or managerial goals. Practical examples demonstrate their use, capabilities, definition and data management. In addition to the company's data structures, higher-level standardised data structures are also covered, as reflected in the IFC specification and the buildingSMART Data Dictionary (bSDD). The use of Collaboration Platforms (CDE) will be discussed based on use cases, as well as open solutions for seamless integration of BIM applications (openCDE) and the resulting impact on collaboration. A distinction will be made between local and

cross-enterprise collaboration. Using a selected software tool, functions such as document management, version management, approval, archiving, documentation, and role and permission management will be explained.

A 2.2 Module practical example (planning, construction, operation) [C+M, 24]
This module begins with a consolidation of the basics using practical examples. One focus is on collaboration between project participants. First, an understanding of roles and responsibilities is established. Building on this, the different approaches of the platforms and tools commonly used in practice are explained and demonstrated using the respective workflows. The scope extends to troubleshooting and building operations. Another key topic will be the use of openBIM on the construction site: Digital (openBIM) site management. The basics of digital site supervision (*ÖBA*) will be taught. The module concludes with the basics of building operations.

A 2.2.1 Planning with model-based communication and collaboration
Acquisition of competences
The participants have a basic understanding of the different working methods of the respective technical planners and are aware of the resulting problems. Depending on the project constellation, the participants can assess which model views, domain models, etc., are used. The participants know possible strategies for coordinated cooperation in their domain model using a coordination model. The participants will be able to lead a coordination meeting independently.

Contents
Based on the work in the openBIM project model with roles and authorisation concepts, it is shown how a digital model can be used for different scenarios – e.g., breakthrough model, connection coordination model, shell model, inspection model, domain model for coordination models. Explanation of the basic openBIM (multi-model-based management information system) working method with the respective discipline–related domain models and the overall coordination model composed of them. The different requirements and wishes of the domain planners and trades will be discussed. The participants will work on typical examples of constellations and exchange workflows – e.g., it will be shown how closedBIM can function partially in an openBIM overall structure. Workflows between project participants related to the »point of view« are carried out using the BCF format. Participants will learn how to prepare and conduct coordination meetings and how to follow up on declared tasks effectively.

A 2.2.2 Digital (openBIM) construction management
Acquisition of competences
Participants will understand the new roles of the local construction authority (ÖBA) through the application of openBIM on-site, where the new roles will be discussed through practical examples of a sample EIR and BEP. Participants will be able to identify relevant digital tools for quality management on construction sites.

Contents

It shows which tasks of the AEC can be supported by the use of openBIM and how this support can be targeted. The focus is on quality assurance, documentation (surveying, e.g., using laser scans and as-built models), verification of product information (from the domain models) and invoicing. Dealing with ad hoc changes on site is a critical issue for which appropriate workflows are presented. In addition, practical examples of EIR and BEP content relevant to AEC are presented, and examples of quality assurance tools and their respective uses are explained.

A 2.2.3 Building operation (product data sheets)

Acquisition of competences

Participants will be familiar with the theoretical underpinnings of building operations in relation to digitisation and BIM. They will recognise the benefits of openBIM for facility management in the handover of building documentation, commissioning, and ongoing building operation. They understand the different digital systems and the relevant standards and guidelines for data exchange to ensure a smooth openBIM workflow. They understand the use of data sheets for building documentation. They will be able to understand the relevant requirements from the BIM regulations for a new building project and, within these requirements, be able to combine the different data from the construction of the building into an as-built model and prepare it accordingly for the transfer of the building documentation to facility management.

Contents

Participants will gain an insight into the areas of building operations for which openBIM is particularly relevant. They will also be given an overview of digitisation in building operations. Relevant terms and backgrounds will be explained in advance and how they relate to the openBIM workflow. This is followed by a direct look at the benefits and opportunities of openBIM in building operations. The focus is on commissioning and the use of data sheets. In addition, the procedure for optimal digital collaboration between BIM and CAFM in a new building project will be discussed in detail. The requirements of CAFM and its integration into the EIR are presented, as well as the technical requirements of CAFM. A practical example of an already implemented BIM-CAFM handover will be presented and discussed.

A 2.3 Module openBIM coordination [C, 24]

In this module, participants will gain an in-depth insight into project implementation according to the BEP and quality assurance of openBIM models. The initial focus will be the creation of the BEP based on the EIR and the associated implications for project implementation (use cases). To fulfil the role of openBIM coordination, rule-based verification and quality assurance of openBIM models are taught using verification software. The software implementation of verification routines plays an important role. This includes the communication of verification results. This allows the quality of technical models and their transfer to be assessed.

A 2.3.1 openBIM projection implementation – application of EIR to the BEP

Acquisition of competences

Participants in the openBIM Coordination need to understand the requirements placed on them by the EIR throughout the project. Participants can establish and maintain a BEP based on the EIR. They will know who is responsible for the BEP and how it can be applied and controlled in the project. They will gain a deep understanding of the subject areas of the different use cases and the associated technical guidelines (LOIN, LOI, LOG) and understand their far-reaching impact on project implementation and project content.

Contents

A sample EIR explains and illustrates the steps required to create the BEP. This is done section by section and always in the context of the service specifications and the associated responsibilities. The *BGK* (BIM Overall Coordination), as the responsible role, must be able to integrate the *BFK* (BIM domain coordination) and the *BPS* (BIM project control) into the BEP creation process or react to project-specific requirements/constellations. These must be described in such a way as to enable the smoothest possible project implementation. The first focus is on the use cases, which (compared to the EIR) need to be specifically formulated for the implementation capabilities of the project participants. The second focus is on the further development of the project (update of the BEP) and the associated adaptation/expansion of the level of detail. Special attention will be paid to the relationship between LOIN (according to EN 17412) and the levels of detail LOI, LOG, and Use Cases.

A 2.3.2 openBIM coordination (quality management)

Acquisition of competences

Participants can use appropriate software to check coordination or domain models and communicate the results, e.g., as a BIM coordinator. They can create their own checking routines (phase-specific model checking using checking rules and documentation in report form) to check requirements from the BEP. They will gain the competence to generate automatic, if necessary discipline-specific, inspection reports from the interaction of classifications and inspection rule sets in inspection software. Participants can communicate relevant reports, evaluations and documentation for further project processing.

Contents

In the beginning, the participants learn the basic working methods of checking software. After an introduction to the functions of the software, the first building models are checked using standard rules. The next step is the adaptation of these standard rules up to the creation of new rules and automated rule sets. Another important part of the software is tools for classification (filtering) and evaluation of model contents. Participants learn how to check model content in a phase-appropriate manner and according to the requirements of, e.g., a BEP, to identify defects, communicate them, and track their elimination. The acquired knowledge will be applied using practical examples.

A 2.4 Module openBIM management [M, 24]

This module includes teaching BIM-specific service specifications in the different service phases and process training. A focus of the module is on openBIM-specific features in the creation of service specifications, rules and regulations, and contracts. Participants will be introduced to quality management strategies and their application in openBIM processes. Participants will learn how to deal with BIM-specific features in project management and the establishment of openBIM project organisations.

Process training introduces participants to process and risk management in relation to the openBIM way of working. The process modelling training is designed to support process understanding. The participants learn processes specific to the openBIM project independently using the process modelling software they have learnt. The module concludes with a block of topics on the transfer of building models to the operational phase of the building (if required, this could be done in a practical workshop).

A 2.4.1 BIM service specifications, rules and regulations

Acquisition of competences

Clients have to provide their organisational units with service specifications. The participants will be able to formulate the corresponding service specifications, determine their allocation and cooperation in the process, and know the existing roles in the process and their tasks. This results in comprehensible requirements for planner contracts etc. The participants will know the structure and design of the EIR as a description of the client's information needs and the structure and design of the BEP and its implementation in the project context. Participants will know how to check compliance with the requirements and how to influence the basis of the contract.

Contents

There are now uniform BIM service specifications, analogous to the conventional service specifications of planners, which clearly define responsibilities in the phase-related BIM processes. The presentation of the different BIM service specifications is followed by an explanation of their scope using practical examples, especially concerning collaboration in openBIM projects.

Another focus will be on the preparation of an EIR. A sample EIR will be used to explain what needs to be considered when preparing an EIR (including objectives, responsibilities, use cases) and, in particular, from the client's point of view when implementing openBIM in the company.

A 2.4.2 BEP monitoring

Acquisition of competences

The EIR requires clients to communicate and monitor their requirements throughout the project. The participants can distinguish between their project-wide and project-specific requirements and perform their control or monitoring functions. This includes monitoring during the preparation of the BEP and its compliance/continuation according to the EIR basis. The service specifications and BIM rules and regulations serve as the contractual basis for the entire course of the project. Participants will learn about the interdependencies and implications.

Contents

This course covers the central BIM topic of the project-specific BEP. It shows how a BEP is created from an EIR and how it is structured and designed. They will learn about the challenges of creating a BEP. Examples are used to explain the implementation of the EIR and BEP in the project and to show which extensions and specifications need to be considered and which roles can have an influence according to their performance profile. The relationship between use cases, LOIN, LOI, and LOG is highlighted.

It is explained how the BIM service specification and the BIM rules and regulations serve as a contractual basis and how they influence the project content in the different phases. Particular attention will be paid to the initiation and tendering/award phases.

A 2.4.3 openBIM project implementation and openBIM organisation (initiation to planning)

Acquisition of competences

Participants will understand the requirements and methods for implementing openBIM projects from the perspective of BIM project management and BIM project controlling throughout the project life cycle. The design process's preparation, initiation and implementation will be examined in detail. Participants will gain the knowledge to identify requirements (from the client's perspective) and the implementation of these requirements in openBIM projects.

In addition to international standards, in Austria national standards should also be considered (ÖNORM): A 6241-2

Contents

Firstly, it will be shown how the requirements for openBIM projects are identified in the preparation phase and how the basics are worked out. The development of objectives and funding models is discussed. This is followed by project initiation. The procurement of requirements and as-built models of existing buildings, the tendering and contracting of design services, and the establishment of the design team and verification of their skills through colloquia (EIR colloquium, modelling colloquium) are discussed. The course then considers ways of monitoring compliance with the specifications. This is followed by an explanation of the various focal points required for successful openBIM project implementation (including openBIM collaboration using domain models, coordination cases, transfer configurations).

A 2.4.4 openBIM project implementation and openBIM organisation (quality management)

Acquisition of competences

Participants will master the functions of checking software and the various components of the checking routine for model monitoring. They will know at what time checking criteria are necessary for quality assurance. They will be able to assemble domain models into an overall coordination model, perform appropriate model checks, communicate identified problems to the relevant model owners and track their resolution. Using the knowledge of service specifications and regulations acquired in previous courses, participants can assign, check and evaluate the required quality criteria for the appropriate service phases based on the specifications in EIR and BEP. Participants will be able to assess the relevance and severity of quality defects and plan and conduct the necessary meetings. This can range from a technical coordination meeting to a project coordination meeting to a BIM audit with the client.

Contents

The respective test criteria for the quality management of the domain models and the composite coordination model are taught. The test criteria range from formal criteria (FCC) to quality criteria (QCC) and integrity criteria (ICC). Examples are used to illustrate and discuss the interaction of the different criteria. Based on the contents of the EIR and the BEP, the requirements for test configurations, the classification of test results, and the necessary contents of test reports are explained.

A 2.4.5 Process management and process modelling

Acquisition of competences

Participants will understand the difference between project and process management. They can identify processes in the company and develop structured process steps from the company strategy and its framework. They can read existing processes for the openBIM tasks in the project team and write their process descriptions (using the Business Process Model and Notation, BPMN).

Contents

After distinguishing between project and process management, the possibility of mapping processes in the IFC data structure is discussed. The strategy and procedure for continuous process improvement will be discussed. Participants will learn and apply a system for classifying processes (core, support, etc.) and their location in a process map. The procedure and templates for process identification and delineation are presented and applied in exercises. As processes are collaborative, the different roles in their development, implementation and improvement are introduced. Using »simple« process examples, the presentation and explanation of BPMN diagrams up to Decision Making Notation (DMN) are discussed.

A 2.5 Modul practical workshop [C+M, 16]

In a collaboration colloquium, the interplay of what has been learnt is then deepened through practical application, from the preparation of the BEP, through technical and inter-disciplinary coordination, to the conduct of an overall coordination meeting. The collaboration workshop aims to clarify the specific challenges of project implementation through practical relevance and to increase mutual understanding between the different project participants.

A 2.5.1 Collaboration workshop

Acquisition of competences

Understand the different modelling approaches and perspectives of the various domains involved in the openBIM workflow. They will be familiar with the different approaches to openBIM within each domain and at the coordination and management levels.

Contents

During the workshop, a business game will be conducted in which the participants will be divided into different groups that will take on the various project roles of the participants in an openBIM workflow in practice. Digital collaboration between the different roles is trained using concrete case studies. For example, the participants will implement the requirements and content of the EIR and BEP regulations in test routines in the sense of collaboration (exemplary implementation of an overall coordination meeting). The focus is on the practical implementation of the service specifications and regulations, the cooperation of the various domains and the sensible implementation of project-specific requirements.

A 3 Certified trainer (bSAT)

buildingSMART Austria's standardised qualification and certification model for openBIM focuses on high-quality functional openBIM training. Therefore, buildingSMART Austria uses Certified Trainers to train BIM users. This certification is limited to three years. Therefore, all Certified Trainers have to be re-certified after three years at the latest. In the certification process, buildingSMART Austria checks the quality, depth, and scope of openBIM knowledge of the future Certified Trainers.

All persons wishing to be certified as Certified Trainers by buildingSMART Austria must have completed a »Professional Certification – Practitioner« for openBIM Coordination and openBIM Management. This means that they already know the training they would like to deliver in the future. Interested parties apply for the certification, which takes place once or twice a year, by writing to the board of buildingSMART Austria. From the pool of applicants, the most suitable candidates are selected for the certification exam.

The certification examination to become a Certified Trainer of buildingSMART Austria consists of the preparation of a written essay and subsequent presentation, including discussion, as well as an examination before an international panel of experts in two parts:

- **Produce a written essay on the future development of openBIM**
  They will be asked to write a practical paper on current or future developments of openBIM or openBIM projects. The written work has a length of about 10-20 pages. This paper has to be submitted to buildingSMART Austria one month before the commission examination.
- **Presentation of the results and discussion before an international panel of experts, incl. examination**
  AFinally, the results of the practical work will be presented and defended before an international expert panel. The commission consists of members of buildingSMART Austria as well as other national chapters (e.g., Germany, Switzerland, Netherlands, Norway, Finland) or buildingSMART International. Presentations are limited to 10 minutes. During the discussion, comprehension questions based on the practical work will be asked. There will be an in-depth examination of detailed openBIM knowledge.

Recertification considers the candidate's intensive involvement with openBIM in the years since their previous certification. The certification exam then consists of an examination before an international panel of experts.

B Collaboration workshop

A useful simulation tool in the context of BIMcert training
Guest author: Hannes Asmera

The simulation is an action-oriented teaching and learning method. As part of the BIMcert training, it is used as an instrument to playfully apply and deepen the previously taught theories of the various areas of BIM in a setting that is as close to reality as possible. The concrete goal is the BIM-based interdisciplinary implementation of a planning task, whereby the focus is not on the planning performance in, e.g., author soft goods, but on the preparation and implementation of the planning processes and the development of the communication skills of all participants.

The following is a brief explanation of the theoretical background and the conceptual structure with the individual roles and tasks of the role play as part of the BIMcert training. In addition, the concrete implementation with all individual steps is clearly outlined, and a conclusion is drawn.

B 1 Theoretical background

The business game is a form of group work characterised by the fact that the participants communicate and learn together. More specifically, a simulation game is a simultaneous and holistic teaching and learning method designed to develop planning and decision-making skills in participants. A simulation game requires participants to analyse complex tasks in a group setting, develop proposed solutions and make decisions within a limited time. In this way, the method enables an interactive, interdisciplinary and dynamic solution to complex problems, and the individual's strengths are used for the benefit of all group members. The business game in the BIMcert training is based on the newly acquired knowledge from the previous modules, aiming to simulate and deepen this theoretical knowledge using a fictitious project with all its roles and challenges under guidance. In addition, the participants' communication and conflict management behaviour can be observed and subsequently reflected upon.

There are different phases in the process of a simulation game:

- preparation,
- allocation of roles and tasks,
- repetition of the phases,
  - problem analysis,
  - solution search and decision planning,
  - resolution,
  - action implementation, and
  - feedback collection, and
- follow-up.

The time frame for this in-depth form of group work is two course days of eight hours each, including breaks.

B 2 Content and organisation of the simulation game

The following is an explanation of the content available and to be generated, as well as the organisation of the simulation game.

B 2.1 Preparation

There are two primary technical requirements or foundations. On the one hand, the shell of the architectural model is provided as an IFC file and in a native file format. On the other hand, the EIR of buildingSMART Austria applies, which has already been explained in the previous modules. This starting point is chosen to get into the interdisciplinary work of the groups quickly.

The authoring and testing software used in the BIMcert training is also used for the simulation, as this is necessary. On the software side, Solibri can be used as a testing tool. Using the authoring software depends on the competence of the participants, and they must be buildingSMART certified. The competences and the software to be used will be requested in advance to ensure a high-quality simulation and to prepare the groups in the best possible way.

A Common Data Environment (CDE) is a platform that allows at least a coordinated exchange of files (e.g., Nextcloud). In this platform, the foundations, the EIR and the shell of the architectural model are available as IFC files and in a native file format. The additional folder structure must provide at least one element for each role. The read and write permissions, which are restricted to the relevant group of role participants, must be considered. In addition, transfer folders are required for the three voting cases (small, medium and large) with the appropriate write permissions for the participants.

In addition to file exchange, BIMCollab Cloud can also be used as part of the simulation. A true CDE platform such as Aconex or ThinkProject is too complex and costly for the purpose and scope of the simulation.

B 2.2 Distribution of roles

Specific roles are assigned to the participants and also to the management of the simulation. The individual roles for the simulation are based on the most important planning participants in practice and are, therefore, only a sample of the actual planning participants.

The number of participants determines the group size. Ideally, the group size should be between three and five people. If necessary, the simulation should be conducted in two parallel groups if the group size requires it.

Client
The client's scenario is to design an office building with a possible extension across the road. At the moment, however, the client is unclear about how to proceed. The planning department takes over this role.

BIM project management (*BPL*)
BIM project management is responsible for the general specification of a project's framework for the client. This includes the service specifications that will be used by each stakeholder and the data structure that will be used in the project. The results of this task lead to the EIR, which is specified here. In the context of the simulation, it may be helpful or necessary for the client and *BPL* to merge into one role and be fulfilled by the simulation management.

BIM project controlling (*BPS*)
BIM project controlling represents the client's BIM interests in the BIM specification and operational implementation of the BIM project based on the specifications of the *BPL*.

These specifications are essentially the EIR on which the BEP is based. This is communicated to the *BGK* and, if necessary, adapted and updated for specific projects.

BIM overall coordination (*BGK*)
The overall BIM coordination agrees and verifies the BIM content of the design participants based on the BIM project controlling specifications for all domains. They are responsible for the coordination model and for monitoring compliance with BIM rules and regulations on the part of the technical planners. The overall BIM coordination is the link between the BIM project management and the design team.

BIM domain coordination (*BFK*)
The BIM domain coordinator coordinates the BIM content of the respective domain based on the specifications of the overall BIM coordination on the project. This role is further divided into three groups:
- BIM domain coordination architecture (ARC)
- BIM domain coordination structural engineering (TWP)
- BIM coordination of technical building equipment (TGA/MEP)

BIM author
The BIM author models the BIM content in the respective domain.

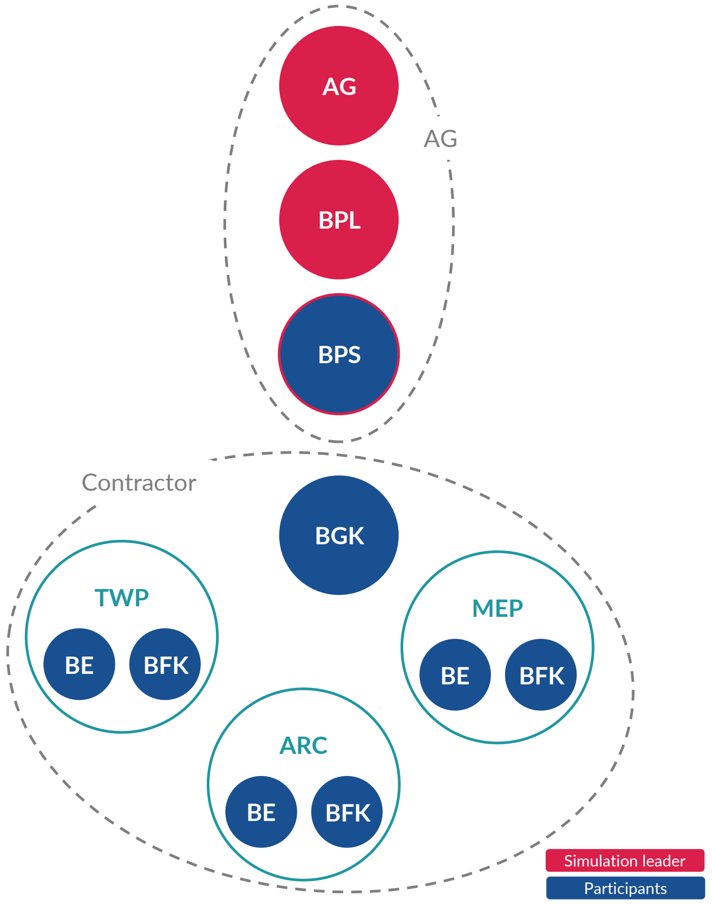
B 2.3 Organisation

The following describes the detailed organisation including the tasks.

Explanation of the task in the simulation game
In the beginning, the basic framework and the task are explained. This is interactive group work to achieve defined milestones within the given time. This is a central part of the picture of a BIM-based design.

At a higher level, all participants are part of the project team. At the second level, a distinction is made between sub-groups. The design team forms groups to create heterogeneous groups. This provides a very good opportunity to look at a project from a different perspective than one is used to in one's usual working environment. It should be noted, however, that there must be a sufficient number of competent people in each group function (e.g., architects with appropriate software knowledge in the architecture group).

The figure shows the organisation of the participating groups and their tasks:



Tasks of the client and the *BPL*
The simulation leader usually does this for didactic and organisational reasons. However, if the simulation's overall duration and group size are extended, it would also be possible for participants to take over the *BPL*. The main task of the simulation management is to support all groups in technical, planning and organisational details and thus to supervise or accompany them throughout the simulation to ensure that the objectives are successfully achieved. The focus is on the process-oriented factors of the project and not on the detailed planning performance. The aim is to conceptualise a project's metadata and examine its initial feasibility critically.

Tasks of the *BPS*
In consultation with the *BPL*, the BIM project management shall develop a project-specific BEP in reduced form based on the buildingSMART Austria EIR. This has to be submitted to the *BGK*. In addition, the CDE platform has to be prepared for its use in the project. The *BPS* also represents the interface between the project participants on the part of the client.

Tasks of the *BGK*
It is the interface between the contractor and the client. Before submitting the BEP, it must prepare the project participants organisationally (as far as possible) and set up the Solibri verification system. The BEP specified by the *BPL* and any updates must also be coordinated. In addition, an overall coordination review and then an overall coordination meeting must be held and documented as a report.

Tasks of the architecture
Once the group has transferred the model provided into their native software, a standard floor (preferably floor 1) will be further detailed as an office use. A façade should also be planned. At defined and appropriate times, but in any case, at milestones of the *BPS*, the architectural model should be made available to the TWP and the TGA as a reference for their planning and coordination. In addition to the production of the technical model, an internal timetable shall be developed in accordance with the BEP of the *BPS*, the LOI of the BEP shall be implemented, and the technical coordination shall be prepared and carried out.

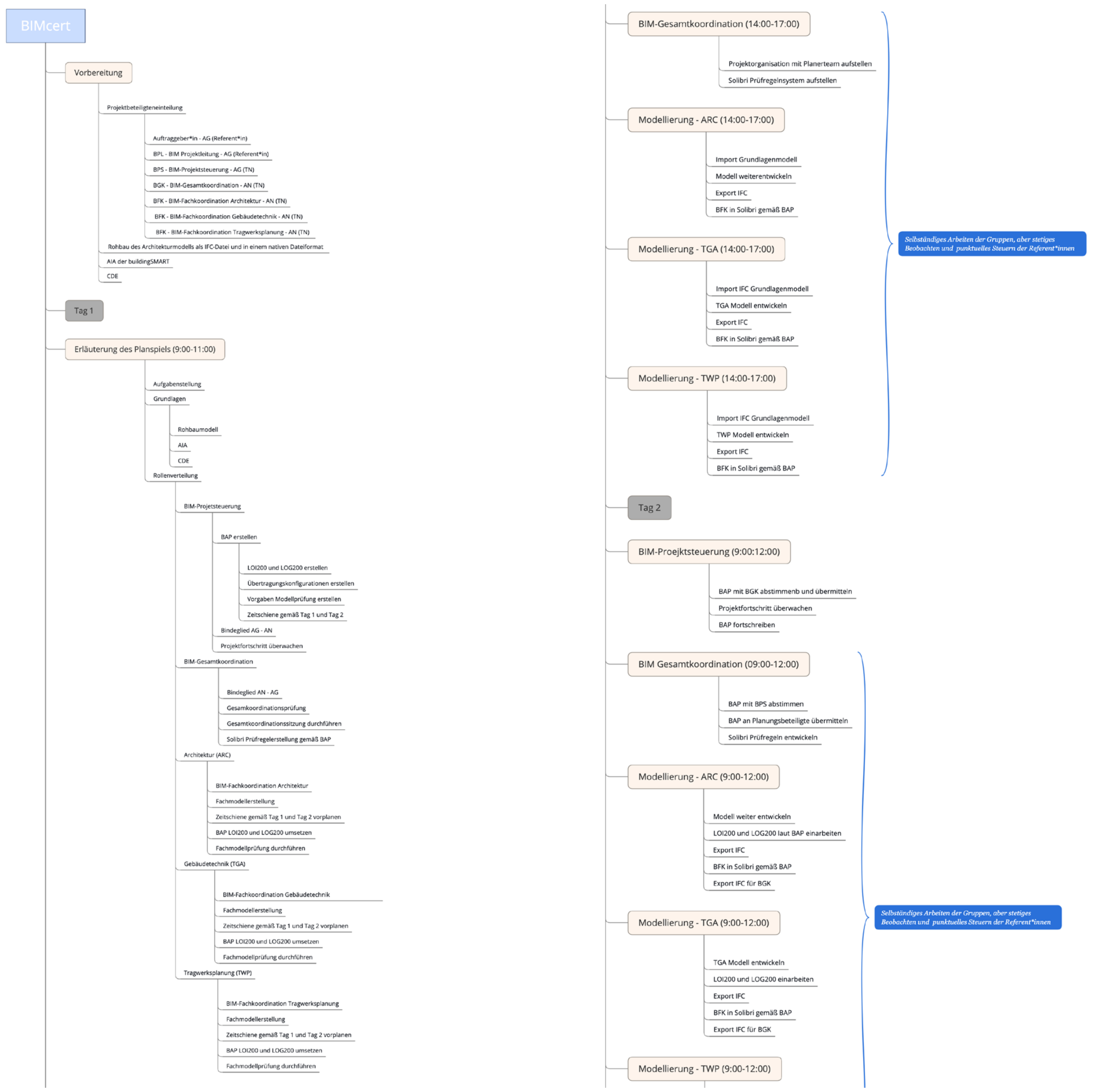
Tasks of the technical building equipment
Based on the building shell provided as an IFC file, functional diagrams and initial central services can be planned. Once the architectural department has further developed the architectural model, the building services need to be extended to include the detailed floor. In addition to the creation of the technical model, an internal schedule must be created in accordance with the BEP of the *BPS*, the LOI of the BEP must be implemented, and the technical coordination must be prepared and carried out. This is based on the milestones of the *BPS*.

Tasks of structural engineering
For structural engineering, a separate model can also be created or transferred to the native software based on the building shell provided as an IFC file. Once the advanced architectural model has been transferred, the models need to be compared, and corrections made to the calculation or LOI if necessary.

In addition to the creation of the technical model, an internal timetable has to be developed in line with the BEP of the *BPS*, the LOI of the BEP has to be implemented, and the technical coordination has to be prepared and carried out. It is based on the milestones of the *BPS*.

B 3 Presentation of a concrete implementation

In the following, the concrete implementation (including timetable) of the simulation game within the framework of the BIMcert training is outlined in detail:



B 3.1 Project start

Once all the roles and tasks of the various planning participants have been communicated, the actual project launch takes place.

B 3.2 Green table

The kick-off with all project participants occurs at the »green table«. The client communicates the requirements for the project, the rough timeframe and the basics. The *BPL* provides the EIR. Then the first internal coordination has to take place. This is done on two levels. The first step is for the groups to agree internally on their structure and rights, and obligations, and then this process takes place across the groups. During this phase, the following points must be taken into account by the participants:

- milestones and project timetable
  The participants are aware of the rough time frame and the required deliverables. Based on this, a realistic schedule for the implementation of the individual tasks and milestones in the project schedule should be defined. This is where the schedules of the individual domains are created and coordinated.
- definition of responsibilities
  Responsibilities shall be defined within the tasks. In the domains of architecture, structural engineering, and building services engineering, at least the following responsibilities and associated knowledge are required:
  - BIM domain coordinator in a senior role and contact person for the *BGK*,
  - reviewer with knowledge of Solibri (including rule creation), and
  - modellers with knowledge of the relevant software (including IFC export and import),

  and in the area of overall BIM coordination:
  - overall BIM coordinator in a senior role and contact person for *BFK* and *BPS* and
  - Reviewer with knowledge of Solibri (also in rule creation),

  and in the area of BIM project management:
  - *BPS* contact person for coordination with *BPL* and *BGK* and
  - BEP responsibility for the creation with a focus on LOI200 and LOG200, the transmission configurations as well as the project schedule.
- checking rule sets
  The handling of checking rule sets needs to be clarified. There are two procedures. Either the *BPS* and the client provide the test rule sets for the *BGK* and the *BFK*, or the individual groups must develop them independently for the *BGK* and the *BFK*. Depending on the size of the group and the time available, a choice can be made here. Either as a requirement of the client or through internal coordination of the participants.

  The following classification of rule sets is mandatory:
  - FCC (Formal Criteria Check):
    These are the so-called fundamental criteria. They mainly include checks for the existence of information and geometries and their logic and basic order. For example, whether rooms exist and are subdivided into a correct room use type.
  - QCC (Quality Criteria Check):
    Here the test criteria are based on the correctness of the FCC. They mainly include the verification of geometric relationships (collision check, distances, etc.) and content relationships (element dimensions, element dependencies, etc.). For example, whether a room has the required room height (= information) without collisions (= geometry).

B 3.3 BIM project management

The first task of the *BPS* is to create a BEP based on the available EIR from buildingSMART. The minimum requirements are:

- The definitions of LOI200 and LOG200 and the element classes to be represented in this form (see table below).
- Preparation of a sufficiently detailed project schedule for planning up to the first overall coordination meeting, including milestones.
- Define the transmission configurations.

Other details that a BEP should contain are desirable, e.g., the project organisation and the use cases in quality management.

It is important to prepare the BEP as quickly and concretely as possible and to submit it to the *BGK*. The BEP must be presented to the *BGK* and agreed upon with them. The first version of the BEP is then released for use in the project. An update or possible detailing or correction must be carried out, and the project's progress must be monitored.

LOI-KLASSE	MERKMALE ÜBERSETZUNG DE	MERKMAL-NAMEN	EINHEITENTYP	EINHEIT	VERORTUNG	VERANTWORTUNG
LOI100	Aussenbauteil	IsExternal	Wahrheitswert	TRUE/FALSE	Pset_WallCommon	AR
	RaumhoheWand	ExtendToStructure	Wahrheitswert	TRUE/FALSE	Pset_WallCommon	AR
	Status	Status	Text (Optionen-Set[92])	-	Pset_WallCommon	AR
	TragendesElement	LoadBearing	Wahrheitswert	TRUE/FALSE	Pset_WallCommon	AR/TP
LOI200	BrandabschnittsdefinierendesBauelement	Compartmentation	Wahrheitswert	TRUE/FALSE	Pset_WallCommon	BS
	BrennbaresMaterial	Combustible	Wahrheitswert	TRUE/FALSE	Pset_WallCommon	BS
	Feuerwiderstandsklasse	FireRating	Text (Optionen-Set[92])	-	Pset_WallCommon	BS
	HauptmaterialitaetElement	ElementMainMateriality	Text (Optionen-Set[92])	-	Pset_WallSpecific	AR
	UWert	ThermalTransmittance	Wärmedurchgangskoeffizient	positive Zahl [W/m²K]	Pset_WallCommon	PH

B 3.4 Overall BIM coordination

The organisation of the project and the system of checks and balances can take place before the BEP is submitted. The milestone is the date of the first approved version of the BEP. As soon as this is available from the *BPS*, it needs to be checked for contractor interests and possibly adapted in consultation with the *BPS*.

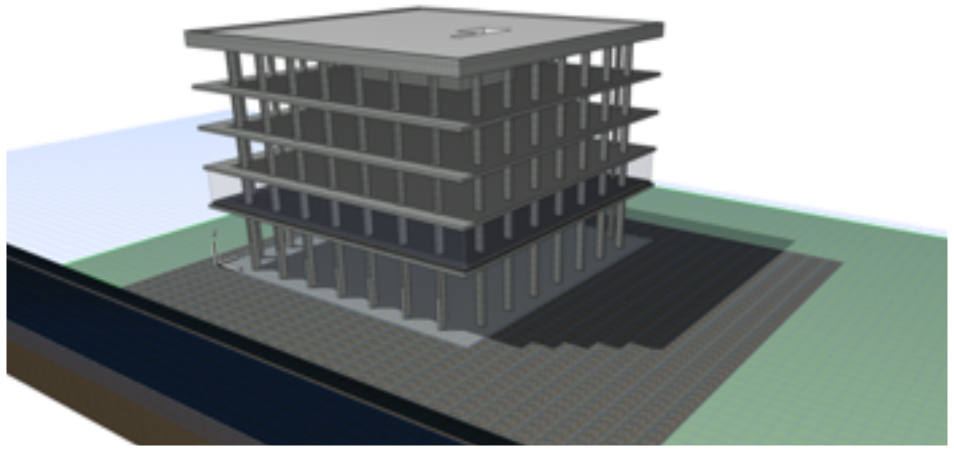
The first fully valid version of the BEP is now communicated to the planners so that they can incorporate the requirements into their planning. On the one hand, developing BEP-compliant inspection rules must be started. On the other hand, care must be taken to ensure that the domain models for the overall coordination inspection are handed over in time. In the meantime, the *BGK* will have to coordinate an updated BEP and describe and ensure the project's progress to the *BPS*.

B 3.5 Modelling architecture

The architecture is based on the provided shell model (see example in the following figure) and develops this model specifically in a control floor. At the same time, Solibri must be used to develop the inspection rules for the *BFK*, as these must also be carried out. These test reports of the BIM technical coordination will be communicated via BCF.

Appendix

B Collaboration workshop



B 3.6 Modelling of technical building equipment

The development of the building services model starts with the provided shell model. The first functional schematics and central services can be planned. As soon as the architect has submitted the advanced model, the building services must be extended and detailed accordingly. For this purpose, the check rules for the BIM technical coordination must also be created in Solibri and then applied to the model. The communication of these check reports is done via BCF.

B 3.7 Structural modelling

A separate structural model is developed based on the shell model provided to facilitate calculations. As soon as the architect has submitted the further developed model, the structural model must be extended and detailed accordingly. It is also necessary to develop the necessary rules in Solibri for the *BFK*. The communication of these test reports of the *BFK* has to take place via BCF.

B 3.8 Overall coordination check

All the domain models are imported into Solibri and assigned to the respective domains. The first step is a visual inspection of the models. The focus is on

- the common origin or correct location
- the apparent completeness of the models
- the use of IFC classes appropriate to the intended use (sampling), and
- the presence of appropriate psets.

The FCC and QCC rules are then applied based on the BEP. When documenting the problems found, a title, description, responsible person or department, priority, and due date for correction must be recorded. The test results are summarised in a test report.

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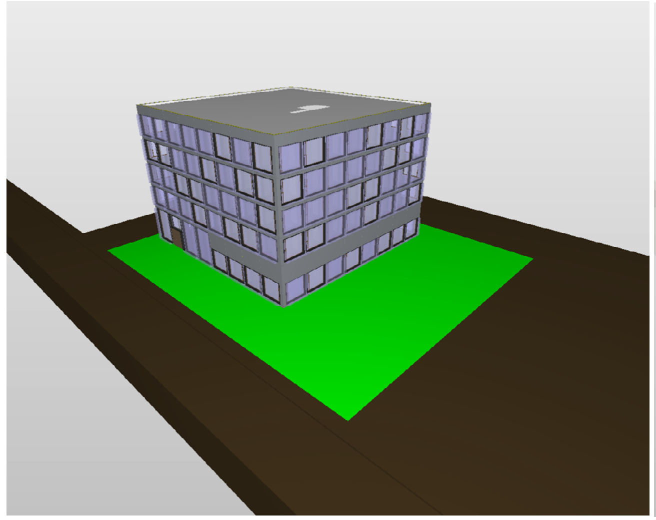
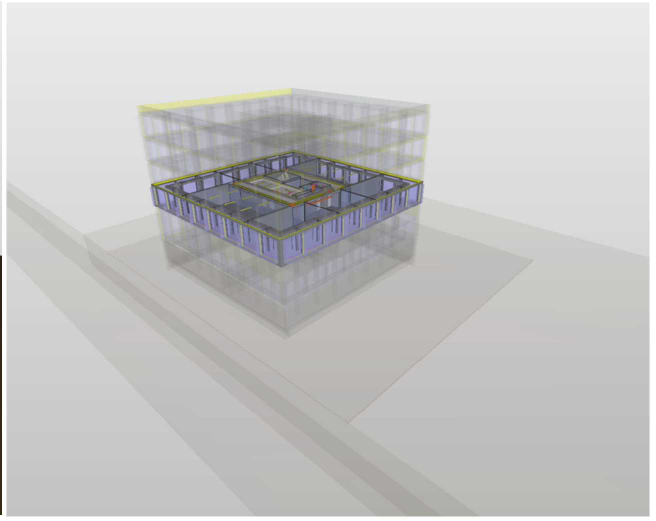
The following figures show a complete model:





B 3.9 Overall coordination meeting

At the overall coordination meeting, the *BGK* presents the problems identified or issues to be discussed in the presence of the *BPS*. Each aspect is discussed individually and, if necessary, the title, description, person or domain responsible, prioritisation or due date for correction is adjusted. It is important that the meeting is well run and that there is good communication between those involved. The review report is attached to the minutes, distributed as a BCF to all project stakeholders for further processing. The following figure shows a complete model in detail.

B 3.10 Summary

This is where the simulation project ends, and a summary is drawn up. In the beginning, the simulation leader gives feedback to the participants on the formal achievement of the objectives in relation to the group's requirements. This is followed by a reflection on the participants' path and potential for development.

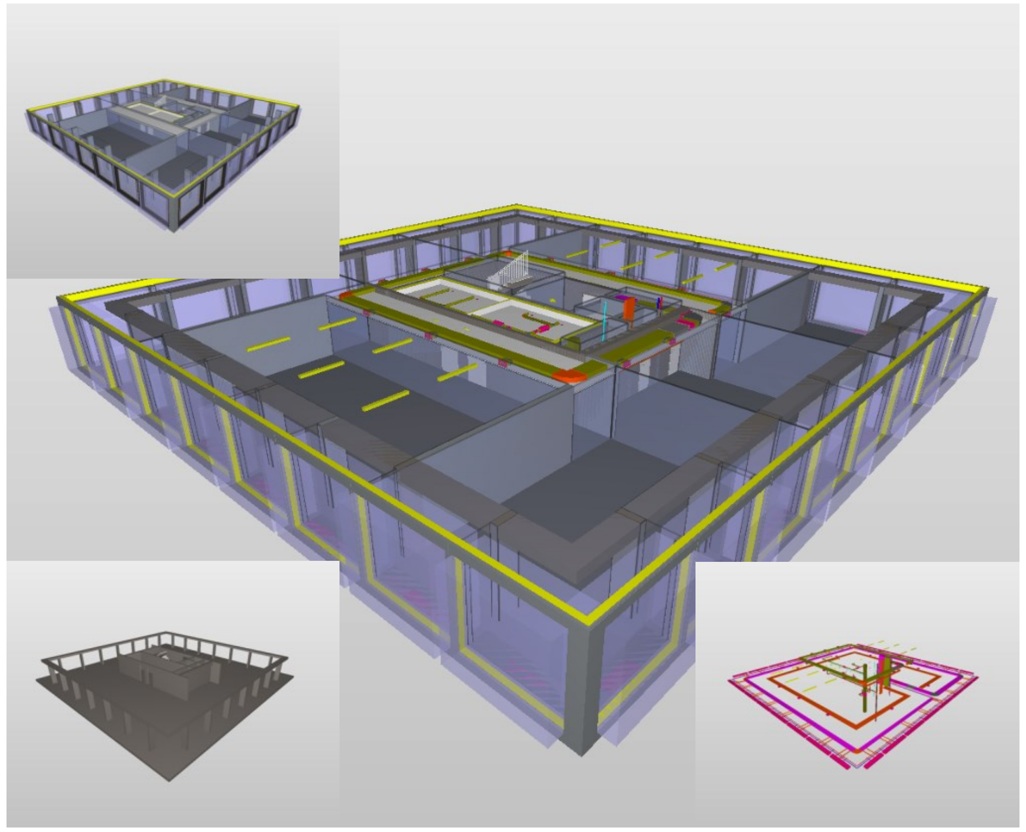
The participants should also reflect on successes and difficulties. If necessary, the facilitator of the planning game can moderate this feedback session.

B 4 Conclusion

There are many advantages to using a simulation in this way. The learning yield is usually higher, as the duration of engagement with the subject matter is usually more intensive. It is important to keep the time sequence and the distance between the learning content and the simulation as short as possible. In addition, the practical application of the learned theory triggers the most profound possible understanding of the subject matter. It also strengthens the group and increases networking.

Disadvantages are the increased time required and the intensive preparation, follow-up and support during the simulation. In addition, the group leader must have a high level of professional and pedagogical competence and act as a counsellor. Therefore, there are high demands on the planning and implementation of the simulation game by the persons involved.

In summary, the business game serves to acquire problem-solving skills, assessment skills, entrepreneurial thinking and acting, and implement knowledge and the holistic experience of BIM contexts, which also facilitates the subsequent transfer to everyday work. For these reasons, the business game presented here is fully justified as an essential component of successful and sustainable BIMcert training.



With the »Professional Certification« program (»Foundation« and »Practitioner«), buildingSMART offers an internationally comparable quality standard for the certification of openBIM knowledge. BIMcert provides the training developed in Austria for this certification. The »Practitioner« certification is covered for openBIM Coordination and openBIM Management.

This book is dedicated to the functional training of openBIM and describes all subject areas for these certification levels. It starts with an overview of digitalisation basics and the most important terms of openBIM. This forms the basis for the »Foundation« certification.

Those interested in theory as well as BIM practitioners will then receive a compact and in-depth insight of openBIM standardisation, IFC, MVD, BCF, CDE, LOIN, IDS, bSDD, and UCM. Armed with this knowledge, BIM practitioners will find the necessary functional knowledge in the chapter »BIM project implementation« in order to then be certified at »Practitioner« level in openBIM Coordination and openBIM Management.

MIRONDE

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