Christoph Carl Eichler | Christian Schranz | Tina Krischmann
Harald Urban | Markus Hopferwieser | Simon Fischer

BIMcert Handbook

Basic Knowledge openBIM

Edition 2024

buildingSMART Austria
buildingSMART Deutschland
BAUEN DIGITAL SCHWEIZ
BÂTIR DIGITAL SUISSE
COSTRUZIONE DIGITALE SVIZZERA
CONSTRUIR DIGITAL SVIZRA
Home of buildingSMART Switzerland

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IMPRESSUM

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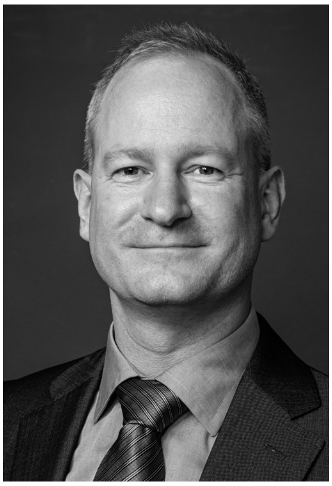

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Simon Fischer
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Léon van Berlo
is the Technical Director of buildingSMART International. Léon previously held various positions at the National Institute for Innovation (TNO) in the Netherlands, including BIMserver Programme Manager and Senior BIM Innovator. At TNO, Léon's work focused on creating a data-driven industry by introducing technologies and developing new concepts. By enabling new prototypes through consensus building and collaboration, Léon developed new products for market-driven demand, including on large EU-funded projects. During this time, Léon also worked on several open standards and BIM standardisation initiatives for international audiences.

Artur Tomczak
is the product manager of the bSDD platform at buildingSMART. He advocates for improving the quality of BIM data and information consistency. At present, he is pursuing a PhD in digital support for circular building design at NTNU in Norway. Before this, he held various roles, from computational engineer, BIM technician and coordinator, sustainability and IT consultant to lecturer.

Jan Morten Loës
is a member of the buildingSMART Product Room and Head of the Research and Development department at VIE Build GmbH, a member of building-SMART Austria. He is involved in several research projects on the topic of product data integrity for digital building models. Another area of research is the integration of GIS and BIM.

Thomas Glättli
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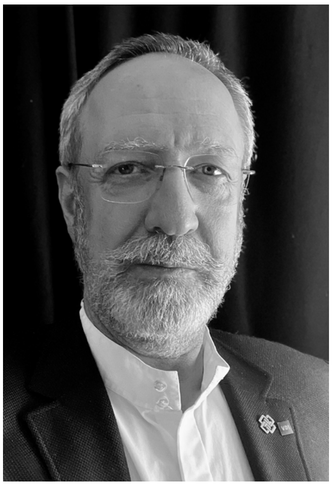

Rasso Steinmann
is Professor of Building Informatics at Munich University of Applied Sciences (for over 28 years). Before that, he worked for 10 years as a software engineer and development manager at Nemetschek. In 2008, he founded the iabi – Institute for Applied Building Informatics, with which he supports BIM standardization and accompanies the industry in the introduction of BIM. He has been involved with buildingSMART International since its beginnings in 1995. He led the group of software houses implementing IFC for over 20 years, was involved in setting up the software certification system and is now Vice Chairman of the Board. He was on the board of buildingSMART Germany until 2023 (8 years as Chairman) and is now an honorary member. At the VDI, he headed the BIM Technical Committee (responsible for the BIM guideline series VDI 2552) from 2013–2023. He is a member of the BIM department at DIN and a delegate to CEN/TC 442 BIM.

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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

Vorwort zur Ausgabe 2024

Time does not stand still – especially in the development of BIM. For this issue, we have focused on two topics: updating and internationalising the content. We have therefore added two experts to our team of main authors: Markus Hopferwieser and Simon Fischer. The technical update includes a complete rewrite of the sections on IFC4.3, Level of Information Need (LOIN), and the buildingSMART Data Dictionary (bSDD). For the latter two, we were able to attract international experts Paul Curschellas (LOIN) and Artur Tomczak (buildingSMART International product manager of bSDD) as guest authors, who wrote the respective sections together with Tina Krischmann (LOIN) and Jan Morten Loës and Simon Fischer (bSDD). In addition, we have expanded Chapter 2 (Basic knowledge) to include introductions to those topics that are covered in much greater detail in Chapter 3 (Advanced knowledge).

Further internationalisation was a frequently expressed wish of our readers, especially from our neighbouring countries. In both Chapter 2 (Basic knowledge) and Chapter 4 (BIM project implementation), we have integrated the ISO 19650 series of standards more extensively, as well as information boxes on national particularities in Austria, Germany, and Switzerland. We have been assisted by 18 BIM experts from these three countries who have provided us with feedback and comments after carefully reviewing the BIMcert Handbook.

We would like to thank Kurt Battisti, Paul Curschellas, Thomas Glättli, Alexander Joslyn, Stefan Kraft, Timo Kretschmer, Anica Meins-Becker, Jörg Meyer, Peter Moser, Christina Ntavela, Ulrich Prestle, Karolina Sadomska, Roman Schneider, Birgitta Schock, René Sigg, Sebastian Toszeghi, Adrian Wildenauer, and Thomas Wirth.

Finally, we would once again like to thank the guest authors for their valuable contributions, the editors for their comments, and all the readers for their positive feedback. Once again, Alexander Gerger is responsible for the typesetting of the book and for the excellent design of all the images (many of which have been redesigned). It is also thanks to the internationalisation mentioned above that buildingSMART Austria (many thanks to Alfred Waschl) is supporting the publication of the BIMcert handbook this year in cooperation with buildingSMART Germany and Bauen digital Schweiz / buildingSMART Switzerland. We would also like to thank these chapters for their always excellent cooperation.

Christoph Carl Eichler, Christian Schranz, Tina Krischmann,
Harald Urban, Markus Hopferwieser, Simon Fischer

Vienna, February 2024

1 Introduction: openBIM and buildingSMART

Building Information Modelling (BIM) is the »next big step« for everyone involved in the design process in the construction industry. It is foreseeable that in a few years' time, as with the introduction of CAD in the last millennium, the entire lifecycle execution process will adapt in such a way that BIM will play a central role. This will require appropriately qualified BIM training in the future. The verification of BIM knowledge must be guaranteed by internationally comparable quality standards for personal knowledge and competence. buildingSMART International has therefore developed a »Professional Certification«.

This book contains the topics for the buildingSMART Professional Certification Programme at the »Foundation« and »Practitioner« levels (openBIM Coordination and openBIM Management). Chapters 1 and 2 cover the basics of digitisation, standardisation (in particular ISO 19650), tools, technology, and organisation required for BIM. This knowledge is essential for the »Foundation« training.

Chapter 3 deepens the knowledge gained in Chapter 2 and covers the key openBIM terms in detail. Starting with an in-depth look at the openBIM standards and a detailed explanation and description of the IFC data structure, the chapter goes on to cover MVD, BCF, and CDE. Finally, guest authors discuss LOIN, IDS, bSDD, and UCM.

Chapter 4 is entirely dedicated to the use of openBIM and provides a step-by-step guide to the use of openBIM in each phase of a building's lifecycle, from project inception through to design and construction. These chapters cover the topics for the »Practitioner« training in openBIM Coordination and openBIM Management.

Info boxes are used to emphasise information. If information is only valid in one country, a flag symbol of the respective country is shown at the beginning of the info box:
🇦🇹 for Austria, 🇩🇪 for Germany, 🇨🇭 for Switzerland.

The QR codes in this book refer either to the sources of the images or to further information. In the digital versions, the QR codes are clickable (as are the cross-references in the text).

1.1 buildingSMART as Home of openBIM

openBIM

buildingSMART recognises the importance of open (i.e. software and vendor neutral) and interoperable solutions and is committed to international, interoperable, open (data exchange) standards for BIM. These provide a comprehensive digital environment for the entire project and asset lifecycle, delivering significant benefits. These open standards can be used for capture, design, documentation, information (data) exchange, and access to building information. openBIM improves the use, accessibility, management and most importantly the sustainability of digital data through open standards. The sustainability of openBIM models is much greater because the longevity of open data formats (due to their openly accessible documentation) is massively greater than when using proprietary data models. Even many years from now, it will be easy to create a programme that can access the open formats of openBIM models. In addition, collaboration between different project participants is facilitated, as they can each access the best (openBIM-enabled) programme for their purpose.

buildingSMART

buildingSMART International (bSI) is an international not-for-profit organisation organised as an association. It was founded in the 1990s as the Industry Alliance for Interoperability (IAI), became the International Alliance for Interoperability shortly afterwards and was renamed buildingSMART in 2005. In the meantime, 33 national organisations (local chapters) have been formed on four continents – e.g. buildingSMART Austria (bSAT), buildingSMART Germany (bSD) and buildingSMART Switzerland (bSCH).

The core objective of buildingSMART (bS) is to improve the exchange of data and information between different software programmes in the construction industry. The aim is to optimise collaboration and digital workflow. For this reason, buildingSMART has been able to attract all major software manufacturers as members.

buildingSMART aims to achieve this through three core programmes: Standards, Compliance and Users.

Core programme Standards

As an independent association, buildingSMART develops its own standards for data exchange and collaboration. These include IFC, BCF, and IDS, with IFC being published as an ISO standard in 2013 (now: ISO 16739-1). In addition, bSI is developing bSDD for the description of objects and their attributes, MVD for the definition of subsets of an IFC data model, and IDM for the description of information requirements. With these standardisations, bSI significantly supports the use of openBIM (BIM with open standards, see QR code).

Core programme Users

This core programme promotes the understanding and use of openBIM standards and solutions. This includes the buildingSMART Data Dictionary (bSDD), the Use Case Management Service, and an IFC Validation Service.

Core programme Compliance – Software Certification
Software vendors can have their BIM-enabled products certified by buildingSMART for correct implementation of IFC. This certification guarantees a consistently high quality of transfer.

Core programme Compliance – Professional Certification
buildingSMART has developed a multi-level qualification and certification system: the »buildingSMART Professional Certification Programme«. This programme consists of four levels in 2024:

- Entry
- Foundation
- Management
- Practitioner

The Foundation and Practitioner levels have been around for some time, while the Entry and Management levels are being developed in 2024. This book focuses on the Foundation and Practitioner levels. The bSI Professional Certification – Foundation« tests basic knowledge and understanding of the use of openBIM in BIM projects. The bSI »Professional Certification – Practitioner« examines the application knowledge of the practical use of openBIM throughout the BIM project, from project initiation to the handover of the building to the client. There are several certification areas at the Practitioner level: openBIM Management, openBIM Coordination, openBIM Specialism, etc.

bSAT Certified Trainer (openBIM experts)
buildingSMART Austria attaches particular importance to high quality, functional openBIM training. This requires highly qualified trainers. For this reason, buildingSMART Austria uses certified trainers (*openBIM experts*) for in-depth training in Austria. They must renew their certification every 3 years. buildingSMART Austria checks the quality, actuality, depth, and breadth of the openBIM knowledge. This examination is carried out by an international expert commission consisting of members of the board of buildingSMART Austria and other national buildingSMART chapters (e.g. Germany, Switzerland, Netherlands, Norway, Finland).

1.2 The History of IFC (Industry Foundation Classes)

Rasso Steinmann (guest author)

The IFC data model as it exists today was not created overnight but is the result of decades of research and development. Documented are the versions of IFC:

- IFC4.3 Add2 (2023)
- IFC4.3.RC4 (2021-07): additions of Rail and Infrastructure
- IFC4.2 (2019-04): withdrawn
- IFC4.1 (2018-86): withdrawn
- IFC4 Add2 TC1 (2017)
- IFC4 Add2 (2016)
- IFC4 Add1 (2015)
- IFC4 (March 2013)
- ifcXML2x3 (June 2007)
- IFC2x3 (February 2006)
- ifcXML2 for IFC2x2 add1 (RC2)
- IFC2x2 Addendum 1 (July 2004)
- ifcXML2 for IFC2x2 (RC1)
- IFC2x2
- IFC2x Addendum 1
- ifcXML1 for IFC2x and IFC2x Addendum 1
- IFC2x
- IFC2.0 (March 1999)
- IFC1.5.1 (September 1998)
- IFC1.5 (November 1997)
- IFC1.0 (June 1996)

IFC2x3 and IFC4 Add2 TC1 are currently in use. IFC2x3 conforms to ISO/PAS 16739:2005. IFC4 Add2 TC1 is equivalent to ISO 16739-1:2018. IFC4.3 Add2 has been ISO standardised since 2024.

Very little is documented about how the IFC came about and what influences have shaped it. The author of this article has witnessed the development in his professional life since 1985 and reports here as a contemporary witness.

The roots

The real starting point for all the data models we know today is the 1960s and 1970s. At that time, it was recognised that computers could not only compute but also process information. By applying the mathematical theory of relations to digital information processing, it was possible to define hierarchically organised structures (*Edgar F. Codd et al: IMS system with the DL/1 language*), which we know today as relational database systems. A completely different approach was the development of networked databases (CODASYL conference, COBOL language), which we know today as knowledge graphs or neural networks.

Relational databases have the advantage of being relatively easy to understand. All you really need to know is that things and processes are represented as tables and the columns of the tables represent the properties of the things. The relations between the things/processes (tables) can be mapped using link references with dedicated properties (table columns). These relations between the tables are structured hierarchically, circular connections (=nets) are to be avoided.

People do best in hierarchical structures and try to organise the world they control as best they can. In network structures (e.g. transport networks), people quickly lose their bearings and need help. The ease of understanding of the relational approach and the ability to use it to implement the popular hierarchies of computing have made it a popular choice.

STEP
This was also the case with the development of specifications for the exchange of product data at STEP (Standards for the Exchange of Product Data), which began in 1984 and was based on its predecessors IGEStop, SET, and VDA-FS. Due to its complexity, the original plan to develop a single, complete product model was discarded, and so in 1994/95 STEP was divided into several parts and submitted to ISO. A key component was and is the data modelling language EXPRESS, which was published as ISO 10303-11. While Part 11 can be used to describe the actual structures of a product data model, Part 21 (.spf, STEP Physical File Format, ISO 10303-21) defines the structures of an ASCII file for exchanging the actual product data (instances of a data model). A few years later, Part 28 (ISO 10303-28) defined how this product data could also be exchanged with XML files. Other basic formats are now available, each of which transmits the same content.

EXPRESS-G can be used to visualise the essential structures of an EXPRESS data schema in a graphic very similar to an entity relation diagram. The proximity to the world of relational data is also evident here.

EXPRESS was then used to specify application protocols for specific use cases, initially focusing on the exchange of geometric data. AP 201 and AP 202 define basic, mainly 2D geometry. AP 204 defines basic 3D boundary geometry. APs have also been developed to describe specific mechanical components. WP 225 focused on building components.

All these APs were heavily influenced by the CAD systems available on the market at the time. The focus was on geometry, to which classifications and some product properties could be attached like flags. To some extent, geometric components could be aggregated into component groups.

Geometry vs. building structure
Many of the foundations for the developments in STEP were explored and developed in EU-funded research projects of the time. There it was recognised that data models for buildings, whose core structure was geometry, were no longer useful. A U-turn followed, and so-called semantic building data models were developed, describing components as objects with attributes that could have relations with each other. This view came to the fore, and from then on geometry played a prominent but structurally subordinate role.

Excursus: With ISO 10303-22 SDAI (Standard Data Access Interface), a standardised interface to databases whose data structures are generated by EXPRESS was published in the last century. In other words, there would have been a standardised technical way to exchange STEP data by connecting software applications directly to a database, instead of having to exchange data with files. Unfortunately, this was rarely used and has been forgotten.

From research to market maturity
In the EU project »VEGA« (Virtual Enterprises using Groupware Applications), a team led by Prof. Richard Junge and his former colleague Dr. Thomas Liebich developed an approach for a »semantic product model« in cooperation with Nemetschek, where the author was still working at that time. This approach was brought to market maturity in the 1990s with Nemetschek's in-house project O.P.E.N. (Object oriented Product Data Engineering Network). A »late binding« approach was implemented, which allowed the data model for the server to be extended at runtime without having to recompile programmes. This strategy made it possible to respond quickly to changing requirements and new applications. This was the first industrial model server for the construction industry that could also be used via the internet. However, this proved to be too early for the market as the construction industry was still too attached to analogue working methods. It was recognised that the processes in the construction industry would have to change fundamentally to achieve productivity gains with this approach, and that a software company alone could not bring about this paradigm shift. A company is not a research institute, so the O.P.E.N. project was discontinued. Subsequent history has shown that the approach was correct, but also that the timing was too early. Even today, a product like O.P.E.N. is still a gamble.

The advantages of VEGA's and O.P.E.N.'s modelling approach were, in addition to a consistent move away from a geometry-centric view, a layered model with a core of common components and topologies and a layer above for domain-specific structures. This architecture, implemented with a »late binding« approach, allowed for a gradual evolution as it was clear that the model would expand considerably, especially for different application areas.

Lack of interoperability
At the same time, a group of companies in the US (including HOK under then CEO Patrick MacLeamy) realised that CAD systems, which at that time were essentially drafting tools, were too limited. The first AutoCAD add-ons offered component-specific functionality, but the data required went beyond the standard DWG/DXF scope and were incompatible with each other. The lack of interoperability was identified as a major stumbling block and led to a collaboration with Autodesk to develop an AFC (Autodesk Foundation Class). Customers in the construction industry were asked to contribute their requirements for such a comprehensive data model. When it was realised that such an approach would require not only the CAD view, but all application areas, it was decided to open this project. In 1995, the IAI (International Alliance for Interoperability, renamed buildingSMART a few years later) was founded and publicised with a roadshow through various countries. It reached Germany during the ACS-95 trade fair, which immediately led to the founding of an IAI e.V. (of which the author has been a member ever since).

The beginnings of IFC
The technical development of the data model was initially the responsibility of Autodesk staff, who were released from their duties for this purpose. After a few missteps, they became aware of the developments in STEP and brought in experts from that community. It was decided to use a modelling approach from Prof. Frits Tolman, from which IFC was developed and presented and discussed in larger groups in versions 0.96 and 0.98. After several prototype implementations, version IFC1.5.1 was the first to be supported by some software systems. Data exchange was proudly demonstrated on discs at ACS 1998.

Anecdote: The world's first IFC file was exported from Allplan, which at the time also supported STEP AP225, so there was sufficient STEP expertise in the development department.

Note: If the STEP rules were strictly adhered to, IFC files exchanged in the STEP Physical File Format should have the extension ».spf«. It was the pride and marketing of the modellers at IAI (buildingSMART) that created the ».ifc« extension, which was then surprisingly accepted by ISO.

As the IFC evolved, it became clear that the chosen approach had a major drawback: the model architecture was too monolithic. Any functional extension required changes right down to the core. It was recognised that such a data model could not be the basis for a global implementation where each software company had its own release cycles. The only way to avoid incompatibilities was for everyone to implement at the same pace and release new versions at the same time. Synchronisation might have been feasible for the small group of interested software houses at the time, but it was illusory for a global implementation.

New start for IFC
In the meantime, it was clear that Nemetschek would discontinue the O.P.E.N. project for the reasons mentioned above. Prof. Junge received permission from Prof. Nemetschek to take the modelling approach from O.P.E.N. with him, thus saving it and developing it further. Shortly after the release of IFC2.0, critical discussion of the emerging difficulties increased. VEGA's and O.P.E.N.'s modelling approach was presented as a solution, which meant a completely new start, but solved the core problem of the previous IFC model thanks to the expandable layer architecture. Thanks to Nemetschek's development experience, they also knew that this new approach would work in principle.

As you can imagine, those who had put their heart and soul into the development of IFC up to version 2.0 were not at all enthusiastic about a fresh start. The result was acrimony. But far-sighted managers at IAI understood that this change was necessary. Jeffrey Wix was appointed project manager, and the new start was implemented, Thomas Liebich took over as head of the Model Support Group (MSG), and the author led the Implementer Support Group (ISG) from the outset and was able to use his experience to show them the way to the new version. This was to be pursued as IFC 3.0, but a 3.0 release so soon after the 2.0 release was considered too humiliating. The diplomatic way out was to call this new approach IFC2x, leaving the '2' visible and the 'x' standing for 'extendable', which most people could swallow.

Of course, IFC2x data was completely incompatible with IFC2.0 data. This was accepted because this effect would have occurred sooner or later with IFC2.0 anyway, and because the group of supporting software houses was still manageable. The majority quickly recognised the benefits of IFC2x, and with STEP expertise available from previous implementations, developers were able to make the switch relatively quickly.

IFC2x
Over the next few years, IFC2x continued to evolve, adding support for the XML format (STEP 10303-28) for exchange files. With the increasing implementation of IFC in various software applications, it became increasingly clear that not all software systems could im-

plement and support the full IFC model. It also makes no sense for a structural programme to support building services or an HVAC programme to support reinforcement. This is why the concept of MVD (Model View Definition) was introduced. An MVD describes a part (subset) of the data model that is required for exchange in specific use cases. During the further development of IFC2x, the so-called Coordination View MVD was established, which supports the technical coordination of the planning trades architecture, structural engineering, and building services in building construction. IFC2x3-CV2.0 marks a stable state and is still the most widely supported IFC version in use today.

IFC software certification

Not all software vendors took the implementation of IFC seriously; for many it was more of a marketing aspect. The lack of support led to a lot of resentment among users, so the author and Thomas Liebich were asked to set up a certification system, which the author has led for 22 years, developing and securing with a consortium for buildingSMART. Many software vendors have now had their IFC2x3-CV2.0 interfaces certified.

IFC4

The next step should have been an IFC version »3x«. However, very few people knew where the »x« in the version numbers came from. However, since the »3« was so prominent with IFC2x3, and since IFC2x was already an IFC 3, they wanted a visible difference and decided to drop the »x« and make it clear that IFC4 also introduced changes to the basic structures. These improvements and new features led to further additions and corrections, resulting in the IFC4 Add2 TC1 version. This version, now in conjunction with the so-called RV (Reference View), is also considered technically mature and is the basis for certification of the software interfaces.

The new b-Cert certification platform has been developed for IFC4, which has implemented a higher level of automation for testing and can also support different MVDs and IFC versions.

Versions IFC4.1 to IFC4.3 have no changes to the core and include extensions to the application layer for infrastructure buildings; IFC4.4 will follow, which will include tunnels.

And what comes next?

This is currently under discussion as IFC5. The author's thoughts on this:
The STEP formats are an area of expertise – comparatively few specialists hold the knowledge. The choice of supporting tools for software development is therefore limited. One could certainly consider replacing the STEP formats with state-of-the-art technical alternatives. This would make it easier for younger software developers to get started, and there would be more supporting tools available. On the other hand, the huge number of IFC files generated to date means that STEP will continue to need to be exported and imported for the foreseeable future. Finally, the Finnish National Library has identified IFC4 as an archiving format.

If you stick with technical underpinnings that essentially implement the relational model, replacing them with more modern variants will ultimately have no noticeable impact on users. What users will notice internally when switching from technology that is still relational is marginal.

This effect was also seen, for example, when switching from IFC2x3-CV2.0 to IFC4-RV, which primarily brings internal technical benefits. The »user experience« with both variants is very similar. As a result, it is very difficult to motivate software houses to switch to IFC4-RV. It is an investment in the future, but with no tangible immediate benefit to the client. In addition, support for IFC2x3-CV2.0 cannot simply be turned off because there are too many of these files in practice – so both versions must be supported, and this saves nothing in development.

This experience shows that a technical improvement that only works internally but is not visible externally is not very motivating for software companies.

Are graphs the future product data?

It is worth considering (and some do) whether it would be the time to leave the relational world behind in product modelling and switch to network-like graph structures. Relational structures reach their limits when hierarchies need to be changed or new aspects added. Although this is possible in principle, it is often very time-consuming. In addition, other data models are created for specific purposes in buildings, which are used in parallel with the IFC. It is unlikely that all these models will be transferred and integrated into the IFC, but rather that they will have to be linked to each other (keyword: »linked data«) to form a digital twin. Graph-based technologies offer great advantages for mapping such digital twins, which are also noticeable in the application. It is no coincidence that these technologies are used to map social networks, which are constantly changing in terms of both hierarchy and content. Aren't our complex construction projects and buildings more like dynamic networks than static hierarchies? The good news is that STEP data models can be automatically converted into the formats required for graph databases. This means that today's IFC data can be transferred to and used in future graph databases.

2 Basic knowledge

This chapter provides the basics for those wishing to prepare for the buildingSMART International »Professional Certification – Foundation«. It provides an easy introduction to *openBIM*. All the basic *openBIM* terms are explained. Everyone involved in an *openBIM* project can therefore use a common language with the same terminology. Therefore, this chapter forms the basis for Chapters 3 and 4, which deal with practical implementation issues. The knowledge imparted in the other chapters also supports the preparation for the buildingSMART »Professional Certification – Practitioner« exam (*openBIM Management* and *openBIM Coordination*).

Important abbreviations are:

ADD	Addendum
AIM	Asset Information Model (Asset-Informationsmodell)
AIR	Asset Information Requirements
AR	Architecture
ASI	Austrian Standards International
BCF	BIM Collaboration Format
BEP	BIM Execution Plan
BPMN	Business Process Modeling and Notation
bSAT	buildingSMART Austria
bSCH	buildingSMART Switzerland
bSD	buildingSMART Germany (Deutschland)
bSDD	buildingSMART Data Dictionary
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
DIN	Deutsches Institut für Normung (German Institute für Standardization)
DTV	Design Transfer View
DWG	Drawing (file extension)
DXF	Drawing Interchange File Format
EIR	Exchange Information Requirements
EN	European Norm
FM	Facility Management
GUID	Globally Unique Identifier

IAI	International Alliance for Interoperability (older: Industry Alliance for Interoperability)
IDM	Information Delivery Manual
IDS	Information Delivery Specification
IFC	Industry Foundation Classes
IFD	International Framework for Dictionaries
ISO	International Organization for Standardization
LOD	Level of Development (outdated)
LOG	Level of Geometry
LOI	Level of Information
LOIN	Level of Information Need
MEP	Mechanical, electrical, and plumbing (building services)
MVD	Model View Definition
OIR	Organizational Information Requirements
ÖNORM	Österreichische Norm (Austrian standard)
PAS	Publicly Available Specification
PDF	Portable Document Format
PIM	Project Information Model
PIR	Project Information Requirements
Pset	Property set
QA	Quality Assurance
QC	Quality Control
RV	Reference View
SE	Structural engineering
SIA	Schweizerischer Ingenieur- und Architektenverein (Swiss society of engineers and architects)
STEP	Standard for Exchange of Product model data
TC	Technical Corrigendum
UCM	Use Case Management
XML	Extensible Markup Language

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 need(ed) improvement. There is particularly high potential for optimisation in terms of reducing 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 can include the following:

- cost reduction,
- networking,
- information transparency,
- technical assistence,
- increased efficiency,
- improved communication and collaboration,
- better risk management,
- flexibility,
- time saving,
- easier monitoring of compliance with regulations,
- establishment of new business models,
- environmental friendliness (less waste of resources),
- increase in productivity,
- competitive advantages, and
- greater attractiveness of employers for new employees.

Definition of BIM as a model and as a process
ISO 19650 defines BIM as »*the use of a shared digital representation of a built asset to facilitate design, construction and operation processes to form a reliable basis for decisions*« (built assets include buildings, bridges, roads, and process plants). This standard thus refers to the three essential aspects of BIM: model, technology, and processes. The core of BIM is the digital building model, which contains the information in the form of geometries and alphanumerics (non-geometric information on function, location, material, etc.). Thus, BIM provides an interdisciplinary, 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 in all phases. This provides crucial support for quality assurance.

Good decision-making requires good data
BIM (Building Information Modelling) is considered a strong driver of digitalisation. 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 can improve 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 a 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 information need. The level of information is referred to as the Level of Information Need (LOIN). It covers the information needs of the client in terms of geometric and alphanumeric model information and associated documentation. Use case serve as a basis for the definition of LOIN and, hence, limit the scope and level of detail. This helps to avoid providing too much or too little information. The level of detail is specified by Level of Geometry LOG for geometric requirements and Level of Information LOI for alphanumeric requirements. The level of development of a model used to be called Level of Development LOD.

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 facility management systems. Operational information can be fed into the model at a very early stage. Target/actual comparisons (GAP analyses) are easier to make. 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 facility management 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 (e.g. 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 designers. 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.

2.1 Digitalisation basics

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 stage (e.g. according to ISO 19650). 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, or information 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 towards digitalisation are:

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

2.2 International 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. As an independent organisation, bSI develops its own standards (e.g. IFC).

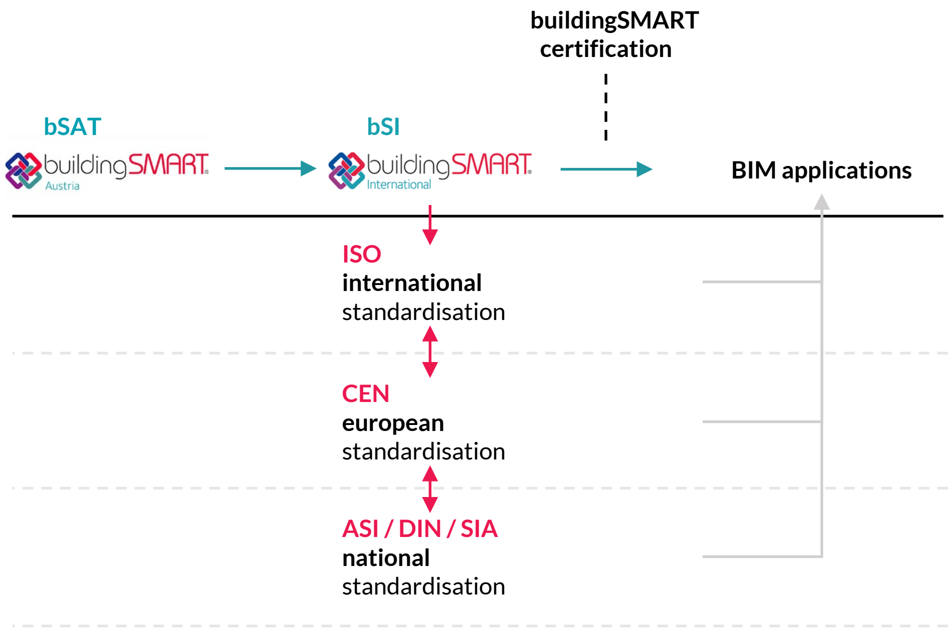

Fig. 2.1: Relationship between standardisations (incl. buildingSMART)

2.2.1 ISO 16739-1 – Industry Foundation Classes (IFC)

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 (since 2018: ISO 16739-1). 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).

2.2.2 ISO 12006-3 – Framework for object-oriented information (for bSDD)

In addition to the data structure, bSI is developing the international property server bSDD (buildingSMART Data Dictionary), 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 assigning labels in multiple languages to the same concept, a multilingual dictionary is created.

2.2.3 ISO 19650 series – Information management using BIM

The title of the ISO 19650 series of standards is »*Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling*«. It consists of 6 parts, with part 6 still under development (as of January 2024). They provide specifications for terms, concepts, and processes that define BIM services and their implementation. Collaborative working using the principles of ISO 19650 by all project participants improves the 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.

ISO 19650-1: Concepts and principles

The first part of the standard describes terms and principles for information management. In the appointment process, there is the appointing party and the appointed party. The former is usually the client or owner and receives the information from the lead appointed party. The appointed party is usually a delivery team, which may consist of the lead appointed party and other appointed parties – it may consist of one person or complex, multi-layered task teams.

Clear definition of roles, responsibilities, authority, and scope of each task is important for effective information management. Responsibilities are defined using a r*esponsibility matrix*. According to ISO 19650-1, a responsibility matrix is a chart that describes the participaton by various functions in completing tasks or deliverables. It therefore defines the *information management functions* (*roles* and tasks), the project or asset information management tasks, and the information deliverables.

In addition to the responsibility matrix, the information delivery planning also includes the definition of a federation strategy and the breakdown structure for information containers. According to ISO 19650-1, an information container is a *named persistent set of information retrievable from within a file, system, or application storage hierarchy*; this could be, e.g. *sub-directory, information file (incl. model, document, table, schedule)*. Federation means the creation of a composite information model from separate (specialised) domain models (information containers). ISO 19650-1 requires that it is specified in the information delivery plan,

- how information will meet the requirements defined in the *asset information requirements* or *exchange information requirements*,
- when information will be delivered (project phases, milestones, specific dates),
- how and what information is delivered and by whom,
- how information from different providers is coordinated, and
- who receives the information.

In information management according to ISO 19650, this standard defines different maturity stages (see also figure). These maturity stages have an influence on different layers: Standards layer, technology layer, information layer, and business layer:

- Stage 1: Combination of 2D CAD planning and 3D models as the standard for planning construction projects and, above all, the use of national standards.
- Stage 2: Consistent application of ISO 19650 (use of information management processes) and national and regional annexes as well as the use of federated information models (compilation of several models).
- Stage 3: openBIM as the standard for the planning of construction projects.

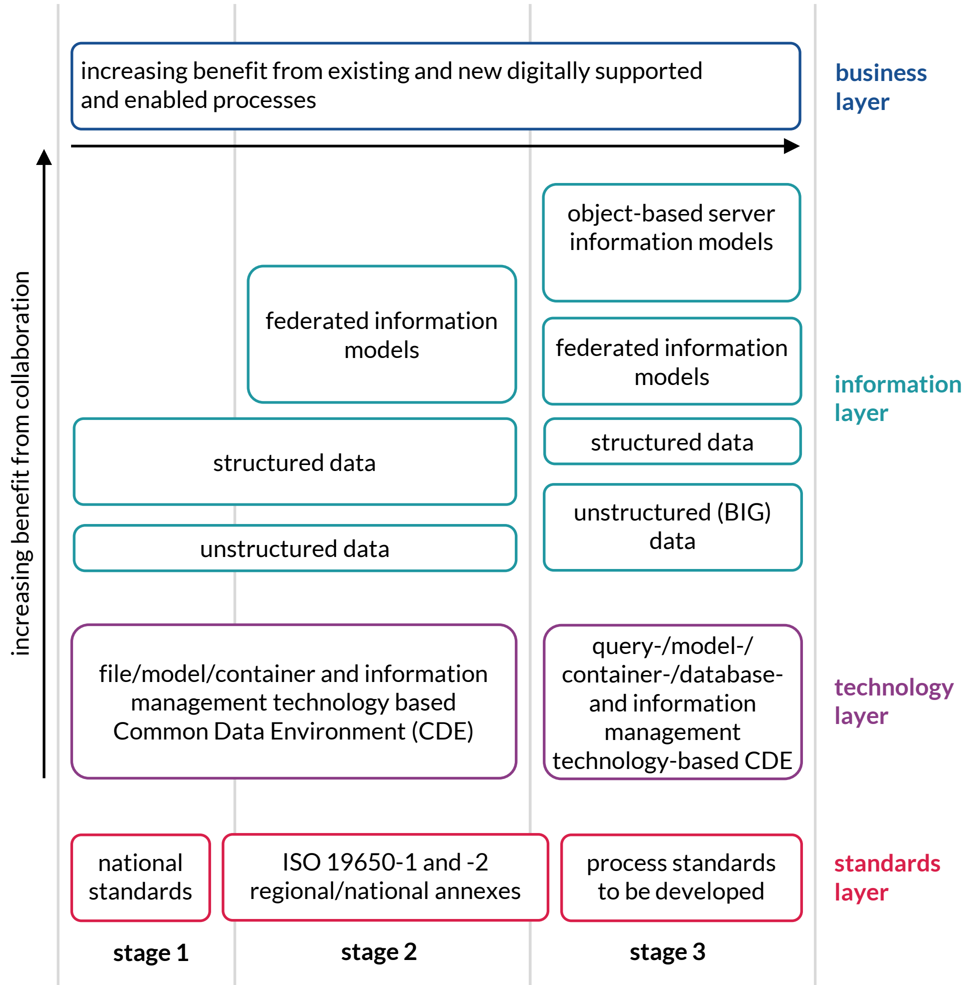

Fig. 2.2: Information management according to ISO 19650 with maturity stages (adapted from ISO 19650-1)

In addition, this standard defines the views of information management. From the asset *owner's perspective*, the purpose of the asset/project needs to be defined and maintained. Strategic decisions need to be made. This includes a business plan, a strategic asset portfolio analysis, a life cycle cost analysis, etc. The true requirements of the *users of the asset* must be identified and assured (structural solution provides the required *quality and capacity*). The project description, an asset information model, a project information model, product documentation, etc. serve this purpose. Project delivery or *asset management* perspective involves planning and organising work, mobilising resources, and coordinating and controlling the development of the project/asset. This is supported by plans (e.g. BIM execution plans), organisational charts, function definitions, etc. The *society's perspective* includes ensuring that the interests of the community are considered in the life cycle. This includes political decisions, area plans, building permits, concessions, etc.

ISO 19650 uses two phases: The *delivery phase* covers the design, construction, and commissioning phases and uses the *project information model* (PIM). The *operational phase* concerns the period in which the building is used, operated, and maintained and uses the *asset information model* (AIM). The asset information model always corresponds to the current state of the building (i.e. it is constantly updated). Both *information models* contain both geometric and alphanumeric information as well as additional information on the performance requirements during design, construction, and operation of the building (e.g. maintenance costs, maintenance schedules) etc. through project documentation. According to ISO 19650, these information models therefore contain structured information containers (e.g. geometric models, schedules, databases) and unstructured information containers (e.g. documentation, video clips, audio recordings). The models have different *information requirements* that influence each other (see figure). The information requirements define what information is to be created, when, how, and for whom.

Organizational information requirements (OIR) define the information need of the client in relation to its organisational objectives within the business. These may arise from strategic business activities, strategic asset management, portfolio planning, regulatory requirements, etc. The OIR provide input for both the **asset information requirements (AIR)** and the **project information requirements (PIR)**. The AIR take into account the business, commercial, and technical aspects of producing information relating to the operation of the asset. The PIR relate to the requirements in the delivery phase of an asset. They are required to respond to the overall strategic objectives of a particular project. The client's overarching project objectives therefore form the basis of the project-related BIM objectives. Both the AIR and the PIR provide input for the **exchange information requirements (EIR)**. These relate to the business, commercial, and technical aspects of producing asset information.

The **AIR** and the **PIR** therefore determine the **content**, **structure**, and **methodology** of the **AIM** and the **PIM**.

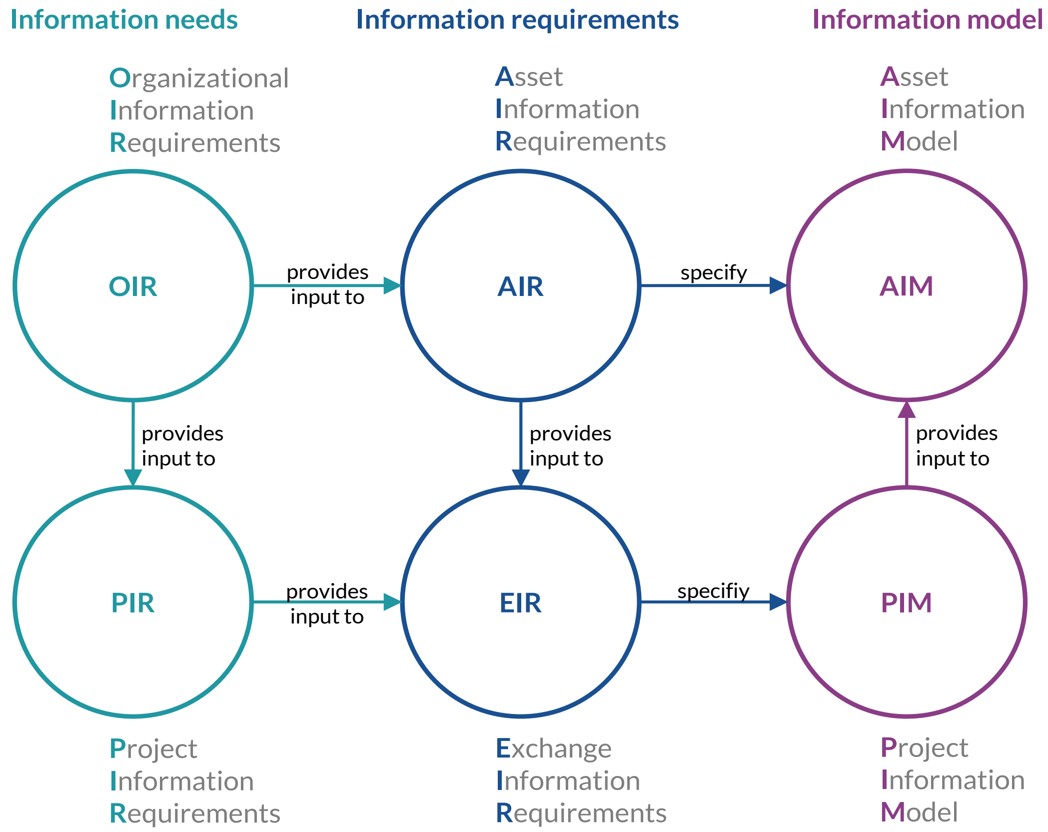

Fig. 2.3: Sequence and dependencies of information requirements (adapted from ISO 19650-1)

ISO 19650-2: Delivery phase of the assets
This part is intended to support an appointing party (such as client, asset owner, etc.) to establish their information requirements during the delivery phase of assets.

For this phase, this standard defines:

- Task information delivery plan (TIDP) as a plan of information containers and delivery dates for a specific task team,
- Master information delivery plan (MIDP) as a plan containing all relevant task information delivery plans, and
- Information delivery milestones as planned events for a predefined information exchange.

ISO 19650-3: Operational phase of the assets
This part is intended to support an appointing party (such as client, asset owner, etc.) to establish their information requirements during the operational phase of an asset, i.e. during asset management and facility management. The defined information management processes can be applied to trigger events, which may be foreseen (scheduled in advance) or unforeseen (unplanned).

ISO 19650-4: Information exchange
This part provides the explicit process and criteria for the information exchange. The aim is to secure the benefits arising from collaborative and interoperable BIM by choosing open schemas, data formats and conventions.

This section introduces the new terms *information provider*, *information receiver*, and *information reviewer*. These terms are particularly important in relation to a CDE and changing the status of information. An *information reviewer* must check information before approving this information to the status »shared« or later to the status »published«. In doing so, they check the information for compliance with the naming (and metadata) requirements of the CDE, conformance, continuity, communication (no degradation or loss due to translation or conversion), consistency, and completeness.

ISO 19650-5: Security-minded approach to information management
According to its own definition, this part provides a framework *to assist organizations in understanding the key vulnerability issues and the nature of the controls required to manage the resultant security risks to a level that is tolerable to the relevant parties*. It is about the reduction of the risk of the loss, misuse, or modification of sensitive information. The aim is to create and cultivate an appropriate and proportionate security mindset and culture across organizations with access to sensitive information, including the need to monitor and audit compliance.

ISO 19650-6: Health and safety information
This part is still in the decision-making phase as of January 2024. According to its own definition, this part describes *the requirement to identify, record, use, and share information on health and safety risks which may result in harm to any person involved in the asset throughout its life; information captured can include any site wide health and safety risks associated with location, previous use, or the sites physical characteristics*.

2.3 Tools

A variety of software products are used in BIM. These are collectively referred to as BIM tools. This category includes BIM software applications, collaboration platforms (C*ommon Data Environments* – CDE), and data structure tools.

2.3.1 BIM software applications

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 BIM implementation documents (EIR and BEP, see Section 2.5.2). Fig. 2.4 provides an overview of the different types of BIM software applications.

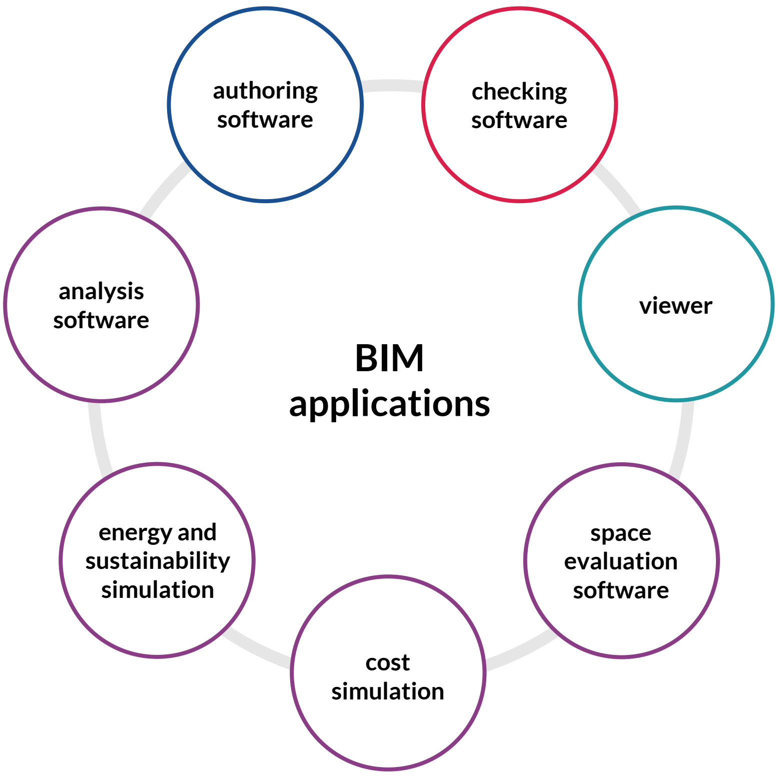

Fig. 2.4: Types of BIM applications

The main BIM software applications 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 considered. 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 Fig. 2.5.

BIM software applications must therefore

- be able to map, derive, and communicate model content according to the IFC data schema / 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.

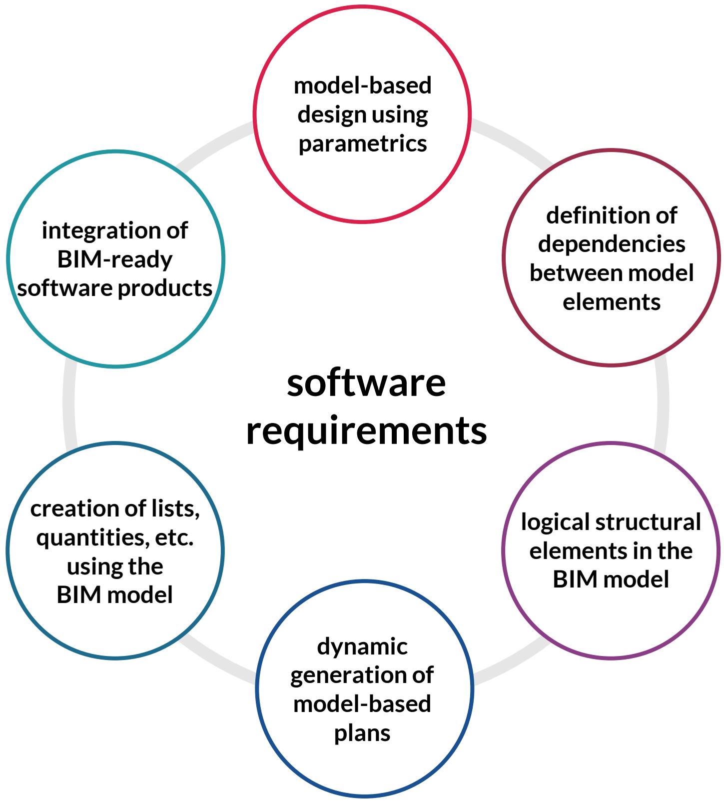

Fig. 2.5: Requirements for BIM applications

2.3.2 Collaboration platforms / Common Data Environment CDE

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 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 Oracle Aconex, Conclude CDE and tpCDE from Thinkproject. For collaboration within a domain, integrated collaboration platforms are sometimes used, such as Autodesk Construction Cloud or Graphisoft BIMcloud.

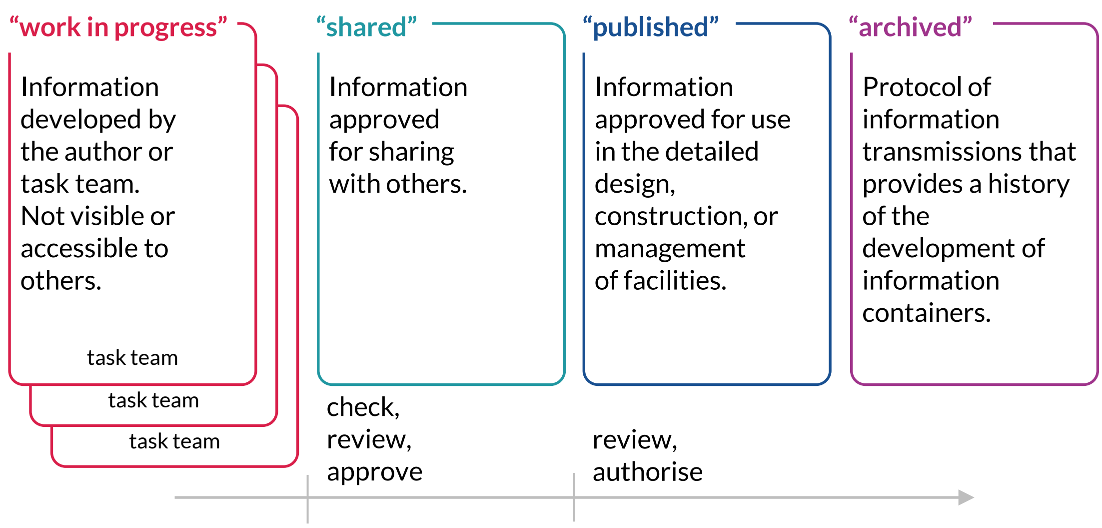

Fig. 2.6: CDE: Information container states according to ISO 19650

2.3.3 Data structure tools

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 *exchange information requirements* and the creation of project-specific BIM implementation documents. 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,
- structuring of associated mappings of external data structures (e.g. IFC2x3, IFC4),
- creation of corresponding mappings of program-specific data structures (e.g. Allplan, Archicad, ProVi, Revit) and the output of the respective configuration files,
- export/reimport of all database content into XLS files for further processing in table editing programs,
- automatic creation of documents describing the data structure specifications (LOI annex of *exchange information requirements EIR*), and
- automatic creation of bases for model-checking routines in BIM checking software.

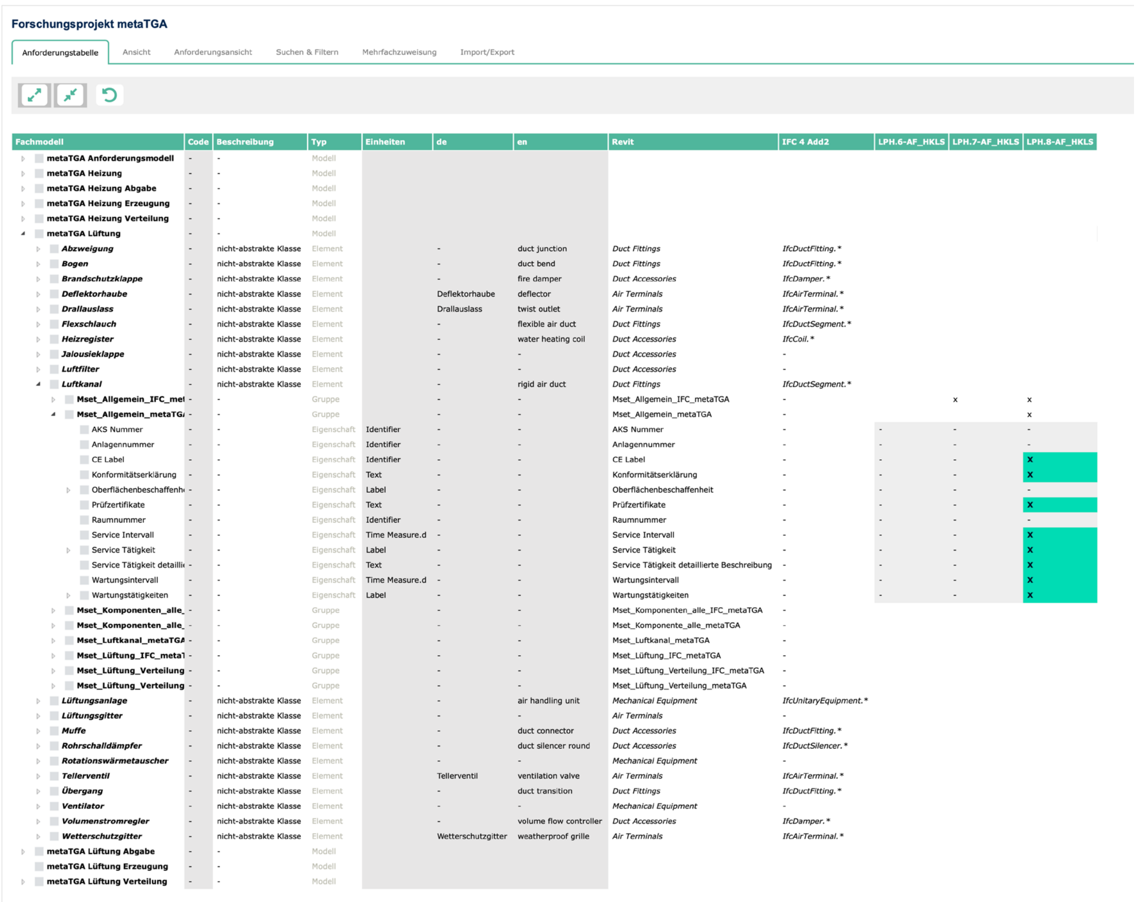

Fig. 2.7: Exemple of a data structure tool (screenshot from BIMQ)

2.4 Technical basics of openBIM

This section introduces *openBIM* in terms of data formats used, services available, and associated methodologies. This includes the IFC data structure, the bSDD platform, the IDM methodology, MVD, IDS, software certification, the buildingSMART validation service, BCF comments, and *DataSheets*.

2.4.1 IFC data schema

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 (since 2018: ISO 16739-1). buildingSMART also recommends using IFC for referencing and archiving models.

With the current version IFC4, all essential domains 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. Fig. 2.8 shows the versions of IFC until now.

The content of the IFC file consists of various classes with attributes, allowing buildings to be described semantically. These can be categorised into different groups. To ensure a clear and comprehensible description, in this BIMcert Handbook the content of the IFC file is divided into five categories (see Fig. 3.19). The main categories are (see Fig. 2.9): spatial level, element level, and resources (material and property).

The spatial level defines the spatial structure of a building in IFC. It declares building sites, the buildings located on them, the storeys within the buildings, and the rooms on a storey.

Buildings are represented by elements (subclasses of IfcElement): e.g. walls, ceilings, columns, doors, or windows. Each element (element instance) is given a unique identifier (GUID). The BIM software applications generate this unique declaration. Each element is optimised to map its functional area. To this end, it carries a standardised basic set of properties to describe relevant characteristics and their typical geometry. The properties are organised into groups (called Psets = property sets). Each element class has a typical Pset containing the most important properties. This Pset is named with the suffix »Common« – e.g. Pset_WallCommon or Pset_DoorCommon. Psets can also apply to multiple element classes at the same time – e.g. Pset_Warranty. All functional elements are associated with storeys and are therefore also associated with a building. In addition to the spatial structure, the elements, and properties (property / property set), the IFC data structure also contains *material information* for declaring material-related properties.

buildingSMART International

Home Standards Services Resources

IFC Specifications Database

Official releases of the IFC specification are listed here, as well as their components including HTML, EXPRESS, XSD/XML, and OWL documentation and formats.

Release Notes and Errata for all versions can be found here.

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Search:

Version	Name (HTML Documentation)	ISO publication	Published (yyyy-mm)	Current Status	Full package	EXPRESS	XSD	pSet XSD	OWL HTML	RDF	TTL
4.4 - dev	IFC 4.4.x development	not started		Extension of 4.3. Adding additional functionality (mainly for Tunnels). Currently under development in the Standards & Solutions program							
4.3.2.0	IFC 4.3 ADD2	Official final buildingSMART standard. Basis for IFC Software Certification.	2023-09	ISO approved. Expected to published by ISO in April 2024.	ZIP	EXP	XSD	ZIP			
4.2.0.0	IFC4.2	-	2019-04	Withdrawn	ZIP	EXP	IFC4x2.xsd	-			
4.1.0.0	IFC4.1	-	2018-06	Withdrawn	ZIP	EXP	IFC4x1.xsd	-	ifcOWL IFC4.1	RDF	TTL
4.0.2.1	IFC4 ADD2 TC1	ISO 16739-1:2018	2017-10	Official	ZIP	EXP	IFC4.xsd	-	ifcOWL IFC4 ADD2 TC1	RDF	TTL
4.0.2.0	IFC4 ADD2	-	2016-07	Retired	ZIP	EXP	IFC4_ADD2.xsd	-	ifcOWL IFC4 ADD2	RDF	TTL
4.0.1.0	IFC4 ADD1	-	2015-06	Retired	ZIP	EXP	IFC4_ADD1.xsd	-	ifcOWL IFC4 ADD1	RDF	TTL
4.0.0.0	IFC4	ISO 16739:2013	2013-02	Retired	ZIP	EXP	ifcXML4.xsd	PSD_IFC4.xsd	ifcOWL IFC4	RDF	TTL
2.3.0.1	IFC2x3 TC1	ISO/PAS 16739:2005	2007-07	Official	ZIP	EXP	IFC2X3.xsd	PSD_R2x3.xsl	ifcOWL IFC2x3 TC1	RDF	TTL
2.3.0.0	IFC2x3	-	2005-12	Retired	ZIP	EXP	-	-	ifcOWL IFC2x3	RDF	TTL

Fig. 2.8: IFC specification data base of buildingSMART (status: January 2024)

2.4.2 bSDD platform

bSDD is short for buildingSMART Data Dictionary. It is a web-based service for creating and using data dictionaries. A data dictionary is a collection of term definitions and the relations between them. It can be used to define objects and their attributes, permitted values, materials, etc. The relations between the individual terms make it possible to create individual classification systems, ontologies, data structures, etc. For example, buildingSMART publishes the IFC data schema as a data dictionary in bSDD. It contains the IFC classes, standardised properties and property sets as well as the hierarchy and relations between the individual term definitions (see Fig. 2.10).

The bSDD serves as a central, publicly accessible platform for data dictionaries. This makes it possible to link content from different data dictionaries. As a result, project partners working in different classification systems can easily translate terms into the other system and improve

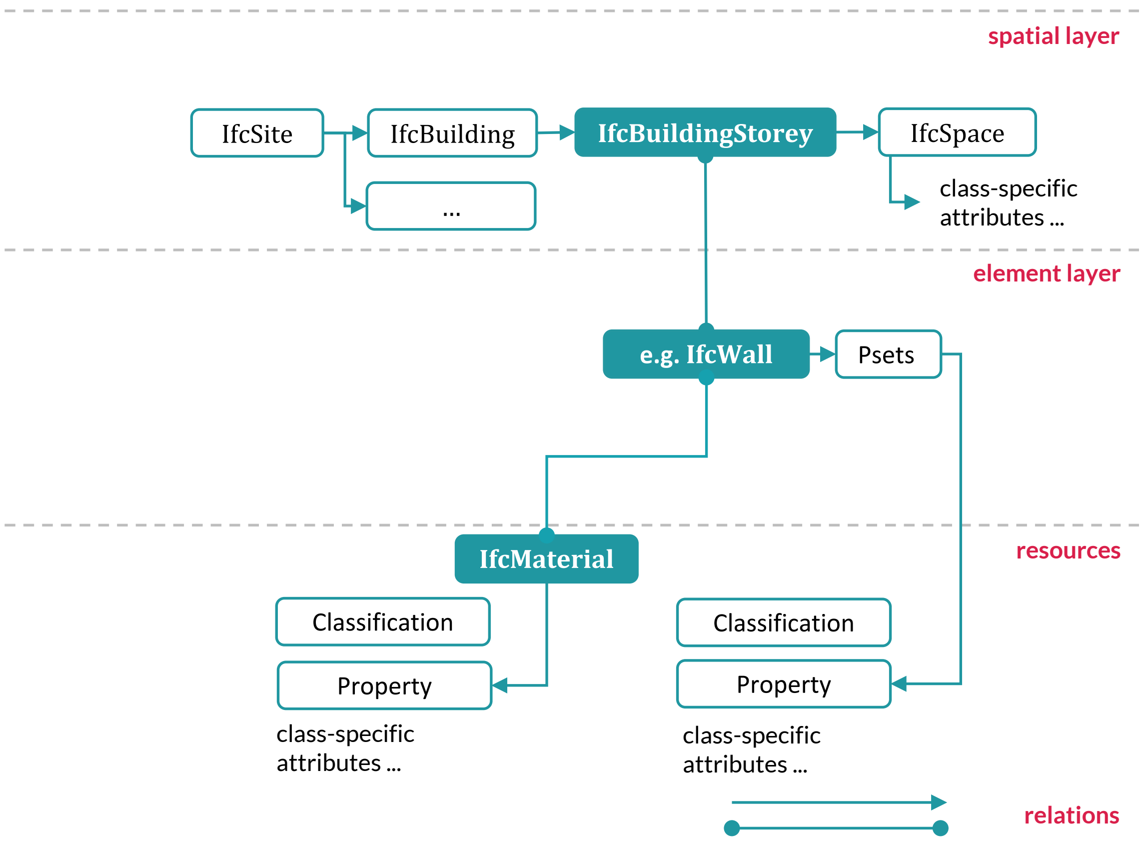


Fig. 2.9: Structure of IFC (simplified illustration, for a more detailed illustration see Fig. 3.19)

collaboration. In addition, referencing existing terms enables a consistent and transparent interpretation of data and avoids duplication of terms. The associated ability to organise multilingualism is also seen as an advantage of bSDD.

In addition to publishing data, the bSDD is a source for the automated data processing. Manufacturers can integrate the bSDD into their software and access the data. This allows models to be enhanced with information from the bSDD. For example, if a wall is also assigned an individual class from the bSDD, the properties and permitted values from that class can be automatically transferred.

Any content stored in the bSDD is owned by the person/institution that created (declared) it. Other persons/institutions can add their respective translations to such a declaration. The bSDD is not a standard, but is owned by buildingSMART. It is based on the open IFD standard (International Framework for Dictionaries) of ISO 12006-3.

An example of content published in the bSDD in early 2024 is the dataholz dictionary from Holzforschung Austria (see QR code). All structure definitions of tested and certified structures for roofs, walls and ceilings from the platform www.dataholz.eu are available in machine-readable and human-readable form.

bSDD
a service by buildingSMART International

Class Property Set

Pset_WallCommon

URI	https://identifier.buildingsmart.org/uri/buildingsmart/ifc/4.3/class/IfcWall/prop/Pset_WallCommon
Class	IfcWall

Class properties

AcousticRating	Acoustic rating for this object. It is provided according to the national building code. It indicates the sound transmission resistance of this object by an index ratio (instead of providing full sound absorption values).
Combustible	Indication whether the object is made from combustible material (TRUE) or not (FALSE).
Compartmentation	Indication whether the object is designed to serve as a fire compartmentation (TRUE) or not (FALSE).
ExtendToStructure	Indicates whether the object extend to the structure above (TRUE) or not (FALSE).
FireRating	Fire rating for this object. It is given according to the national fire safety classification.
IsExternal	Indication whether the element is designed for use in the exterior (TRUE) or not (FALSE). If (TRUE) it is an external element and faces the outside of the building.
LoadBearing	Indicates whether the object is intended to carry loads (TRUE) or not (FALSE).

Fig. 2.10: Standardised properties of property set Pset_WallCommon in the bSDD

2.4.3 IDM methodology

The exchange of models and model information between organisational units requires technically well defined descriptions, terminology, and interfaces. The IDM (Information Delivery Manual) methodology supports the description of information requirements in connection with the processes within the lifecycle (*use cases*). IDM has been developed by buildingSMART and certified as an ISO standard (ISO 29481-1 and -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).

Stakeholders along the value chain of an asset use IDMs to describe their information needs. The following questions should be answered:

- Who are the stakeholders and what are their interests?
- What model information is needed?
- What additional inputs are needed?
- What does the originator provide and what does the recipient require?

The result is a document consisting of an interaction map / transaction map and/or a process diagram and exchange information requirements EIR. The interaction map defines the roles involved and their transactions. The process diagram adds a chronological sequence of activities. According to ISO 29481-1, each IDM component (interaction map, process diagram, exchange information requirements) requires administrative data (header data) and a short description of the content, use case, objective and scope of the component.

An IDM thus defines the scope and type of information requirements that must be requested or delivered by specific BIM management functions (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, as the relevant data transmitted must be communicated in such a way that the receiving software can also interpret it correctly.

ISO 29481-2 defines IDM zones from the perspective of user requirements and the technical solution (see Fig. 2.11).

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

For Germany, VDI 2552 Part 4 provides the following procedure for creating an IDM:

- definition of roles and tasks,
- definition or recurring processes and actions,
- determination of required information,
- specification of the information to be exchanged,
- mapping of the information to be exchanged in the data model, and
- creation of the corresponding Model View Definition (MVD).

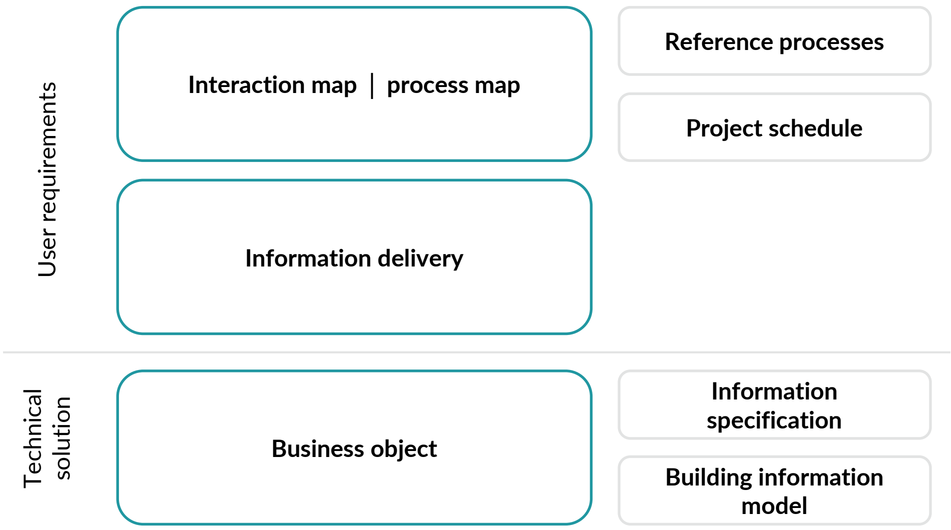


Fig. 2.11: IDM zones from the perspective of user requirements and technical solution

2.4.4 UCM platform

UCM (*Use Case Management*) is a buildingSMART platform for the public provision of use cases, their processes, and requirements that have been developed according to the IDM methodology. It shows best practices of use cases that can be adopted by other users in their projects. Users benefit from processes and requirements that have already been developed and have proven themselves in practice for a specific domain.

In addition to a general description, UCM entries according to IDM contain a process map and process description as well as information requirements (e.g. required properties). This means that all included use cases use a standardised structure and common language, regardless of the phase for which a use case was developed. The defined information requirements form the basis for translating them into specific technical requirements for BIM models. Depending on the type of requirement, these can be formulated as MVD or IDS.

2.4.5 MVD concept

The processes and information defined in an IDM are translated into precise technical requirements (machine-readable) in so-called MVDs (Model View Definition). They represent a process-related subset of the entire IFC schema. The IFC schema defines classes for a wide variety of objects and concepts in the building industry that are required for different use cases. A classic use case is design coordination between the domains of architecture, structural engineering, and building services (MEP, FM handover). This coordination requires classes for objects from all three domains (e.g. walls, columns, pipes). Classes to describe actions on the structure are not required. In addition, IFC offers different options (classes) for mapping geometry, e.g. only as a surface or according to creation (extrusion of a profile). For design coordination software, information about the surface of an object is sufficient. MVDs can define such restrictions. They describe a data exchange for a specific application or workflow (application-specific data exchange requirements) and specify software 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 façade system).

They provide guidance for all IFC expressions (entities, relations, 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. As different MVDs also require different software implementations, costumers should not develop their own MVDs, but should refer to the official MVDs to be used in projects. BIM implementation documents (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 domains of architecture, structural engineering (structural analysis), and building services (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 domains of architecture, structural engineering, and building services.

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.

2.4.6 IDS format

Another option for the technical specification of information requirements from use cases is IDS (Information Delivery Specification). IDS is a new standard from buildingSMART for the computer-interpretable definition of *exchange information requirements*. The difference to MVD is that IDS focuses on alphanumeric requirements. An MVD mainly plays a role in software development to ensure that the required classes can be processed in the software, e.g. for geometry processing, spatial structure, or property assignment. For alphanumeric properties, the MVD must therefore define that properties can be created and assigned. However, the IDS can specify which properties with which content (values and units) should ultimately be assigned to which objects in a project. It is therefore perfectly suited to defining the alphanumeric information content (Level of Information – LOI) in a project.

Traditionally, the LOI is often provided in Excel spreadsheets and PDF files. With IDS, there is now a standardised, computer-interpretable format for integrating this information into the automated BIM process. This can be done in two places:

- as a configuration file for authoring software to automatically create the required information structure, and
- as a configuration file for checking software to automatically fill in checking rules.

This closes the information loop between the definition and testing of model content.

IDS also offers new ways of defining model requirements more precisely. Previously, alphanumeric information was usually specified at class level (e.g. required properties for IfcWall). With IDS, requirements can also be made dependent on specific attributes, properties, external classes, relations, and materials. For example, a concrete quality property is only required if the material of an object is concrete. Or the fire rating values of a wall may only begin with »R« if it is load-bearing (e.g. REI90). This corresponds to a specific filtering of the elements concerned and allows users to define their requirements more precisely.

Technically speaking, IDS is an XML file with a schema specified by buildingSMART. This open, simple schema allows IDS to be easily interpreted by computers and humans. It helps to precisely define information requirements and, in combination with other buildingSMART standards (bSDD and UCM), ensures unambiguity and clarity.

2.4.7 Software certification and IFC validation service

IFC is integrated in all common BIM software applications. Software certification by buildingSMART International ensures consistently high transfer quality. This software certification is currently undergoing a change. Certification is currently performed for Model View Definitions (technical implementations of use cases) that are officially defined by buildingSMART. This MVD-based software certification is a paid service provided by buildingSMART that can be used by software vendors. It ensures that certified software can create and process IFC files according to these very general use cases.

A new, publicly available way to check the quality of IFC files from any software is the buildingSMART Validation Service (see QR code). IFC files can be uploaded to this platform to check their form. First and foremost, the Validation Service checks that an IFC file conforms to the IFC standard. This includes checking the syntax (STEP physical file), the

IFC schema used (e.g. IFC4) and other rules of the IFC specification (e.g. a polyline must not contain duplicate points). In addition to conformance to the IFC standard, conformance to referenced classifications from the bSDD can be checked, if available in the IFC file. Fig. 2.12 shows the Validation Service interface including the test results of an Archicad test model. This model is publicly available on the TU Wien research data platform (see QR code). Apart from the content of the bSDD, the Validation Service does not check the actual content of an IFC file, such as the presence of special properties. It also cannot check IFC files against IDS requirements. The Validation Service is used for technical validation of an IFC file, not for content validation.

Software vendors can use the Validation Service to validate their IFC implementation (currently limited to exported IFC files). For IFC users, the Validation Service allows them to check the quality of the IFC files they receive. Overall, this can improve the technical quality of IFC files and thus increase interoperability between different BIM software applications.

In the future, this system might be used for the official certification of buildingSMART software. The validation service is currently available as a beta version and can be used by anyone with a free buildingSMART account.

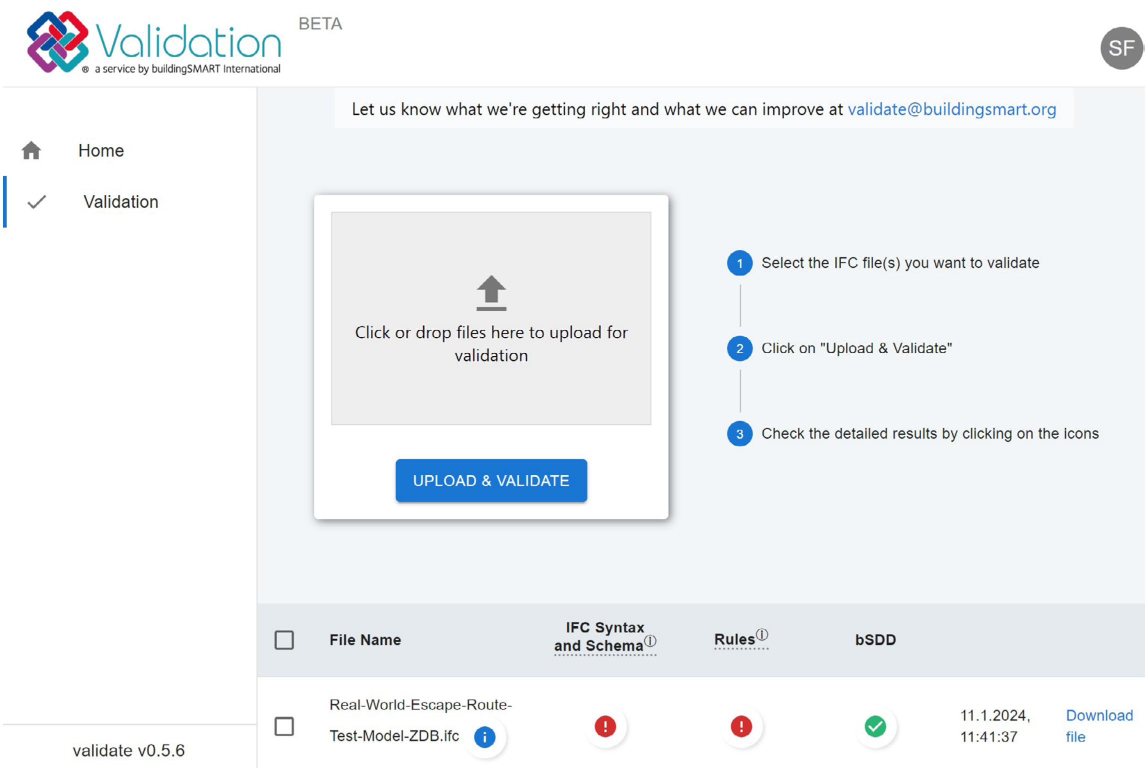


Fig. 2.12: Web interface of the buildingSMART validation service (Status: January 2024)

2.4.8 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 3.0 allows the transfer of

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

as XML-formatted data between different BIM software 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 software applications. In some cases, special additional modules (AddOns) are required to extend the range of functions.

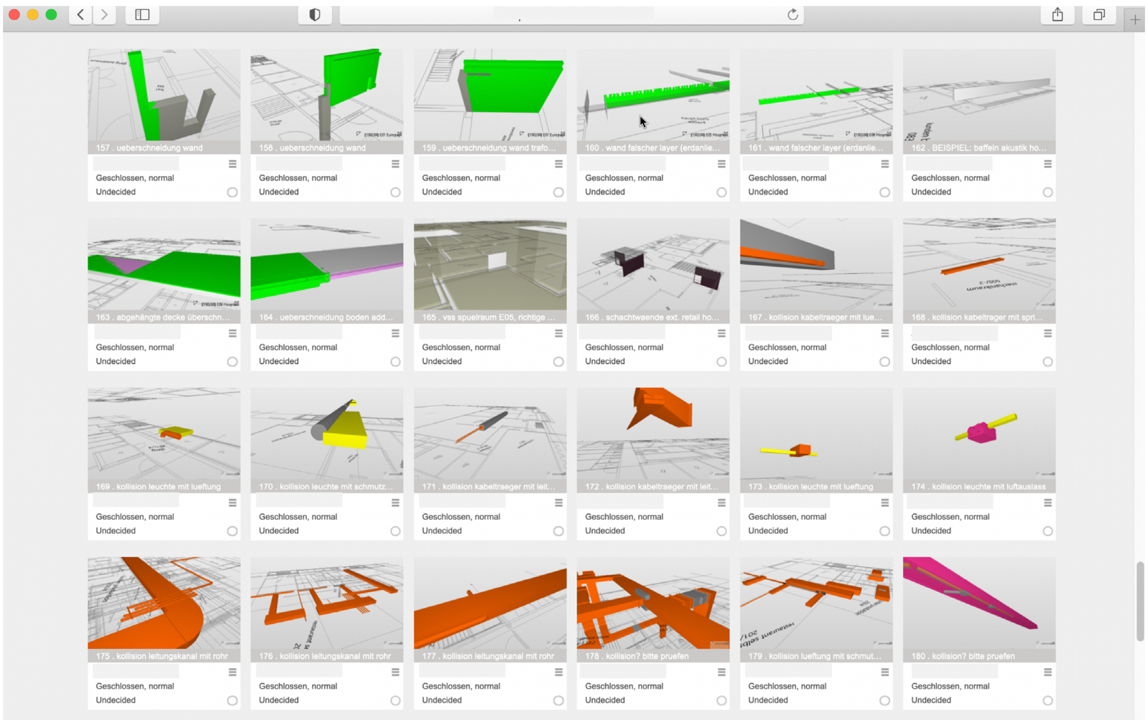


Fig. 2.13: Example of a BCF use in a project

2.4.9 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 (EPD), which will be normatively regulated by ISO 23386 from 2020.

The structure, composition, and content of the *DataSheets* 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) 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, construction, industry, and logistics – the construction of a continuous data chain to building products will become a reality.

The interaction between *DataTemplates* or *DataSheets* and IFC-based digital models is governed by ISO 23387. This refers to the bSDD when declaring features of a *DataTemplate* or *DataSheet*. In this way, features of different products are coordinated and not redundantly created. The transfer of a *DataTemplate* or *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* or *DataSheets* into BIM applications is still in preparation.

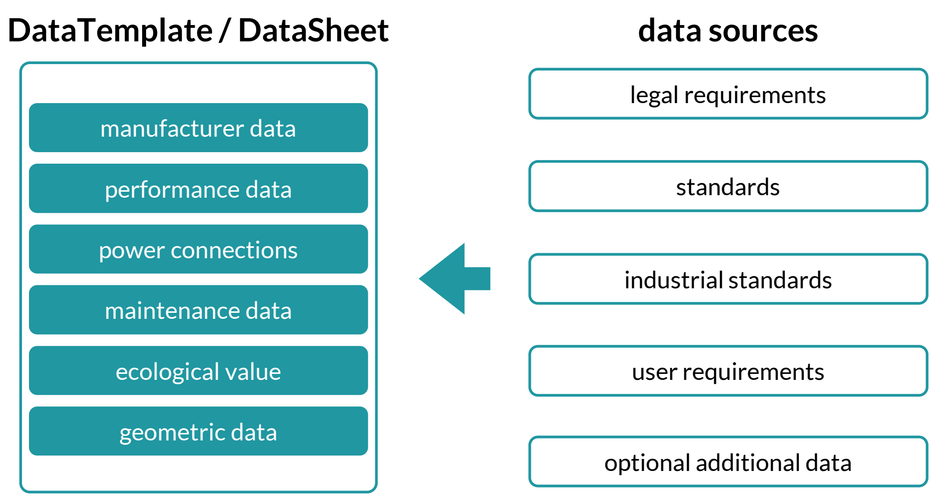


Fig. 2.14: Data sources in DataTemplate/DataSheet

2.5 Organisation

This section covers the BIM-relevant organisational topics of roles and service specifications, BIM implementation documents, and collaboration in *openBIM*.

2.5.1 Roles and service specifications

Traditional service specifications do not currently contain any specific information on the basic services required for the proper execution of the project contract in relation to BIM. It is therefore necessary to define separate roles and service specifications (= BIM service models) for BIM projects. However, the roles (or BIM organisational units) in the project must refer directly to BIM tasks and BIM services in order to call them up. The use of BIM service specifications is not mandatory but is recommended.

Established BIM service specifications (LM.BIM) are currently freely available from buildingSMART Austria (see QR code). These are already being used in numerous BIM pilot projects by private and public clients. The first version of the service specifications was made available by buildingSMART Austria in 2019. Updated versions have been published based on experience gained in projects and further developments (currently LM. BIM 2024).

In Germany, the guidelines VDI 2552 Part 2 and VDI 2552 Part 7 contain specifications for the roles and service profiles. The HOAI (Official Scale of Fees for Services by Architects and Engineers) is currently being amended in Germany. The 1st amendment stage has been completed. In an expert procedure, the design areas of the HOAI were evaluated and proposals for changes were developed. Since the last reform, design and construction requirements have evolved. For this reason, issues such as sustainability and climate protection, construction in existing buildings and, in particular, the use of digital methods must be given greater consideration in the HOAI. In the first phase, the service specifications were synchronised and updated, new service specifications were added (urban design) and a standard BIM process was developed.

In Switzerland, Bauen Digital Schweiz publishes an information sheet on the roles and services (see QR code).

The main objective of the BIM service specifications is to create a common understanding between the client and the contractor of the scope of services to be provided

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

The medium-term goal of unified BIM service specifications is the creation of associated standard terms of compensation. The BIM service specifications flow into the BIM Execution Plan (BEP) via the Exchange Information Requirements (EIR). They form the basis for the content on 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 BIM organisational unit in the overall structure, the description of the general and cross-project-phase services, and the specific project-phase-related services.

BIM service specifications 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 services to be provided, and
- modify responsibilities due to changed project constellations.

The BIM service specifications describe the roles and services of the BIM organisational units (= *information management functions* = *BIM roles*). Examples of this are:

BIM Management (sphere of the client)**:** In some projects, *BIM Management* is divided into *BIM Management (client)* and *BIM Management (control)*. This means that all tasks of both organisational units become the responsibility of *BIM Management*.

Note: In this BIMcert Handbook we use the organisational units of *BIM Management (client)* and *BIM Management (control)*. If *BIM Management* is not divided into these units, *BIM Management* comprises the responsibilities and tasks of these two units.

BIM Management (client): Qualification at the level of the owner/client. This is the responsible body 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. *BIM Management (client)* is responsible for creating the EIR. *BIM Management (client)* often creates the preBEP based on the EIR.

BIM Management (control): 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 specifications of the *BIM Management (client)*. *BIM Management (control)* monitors the creation and maintenance of the BEP and approves it when the client's specifications and objectives are met in accordance with the EIR regulations.

In accordance with the older BIM service specifications LM.BIM 2019 of buildingSMART Austria, the BIM Management (client) creates the preBEP based on the EIR. However, BIM Management (control) could have also been responsible for the creation and further continuation of the BEP. With the LM.BIM 2022 service specifications, this responsibility was transferred to BIM Overall Coordination.

BIM Overall Coordination (sphere of the contractor): It coordinates and verifies the interdisciplinary *openBIM* content of the parties involved based on the *BIM Management (control)* specifications. It is responsible for the coordination model and monitors the implementation of the specified tasks of the domain coordination. *BIM Overall Coordination* is responsible for the preparation of the *BEP*. In terms of coordination, the *BIM Overall Coordination* is closer to the contractors (project participants) and therefore has a better insight into the current needs of them. As a result, the *BIM Overall Coordination* is responsible for creating and further adapting the *BEP* as the project progresses. *BIM Overall Coordination* is the primary point of contact for the digital design to the *BIM Management (control)*, which monitors and approves the *BEP* during its creation and ongoing adaptation. In summary, *BIM Overall Coordination* is therefore responsible for the operational implementation of the BIM objectives.

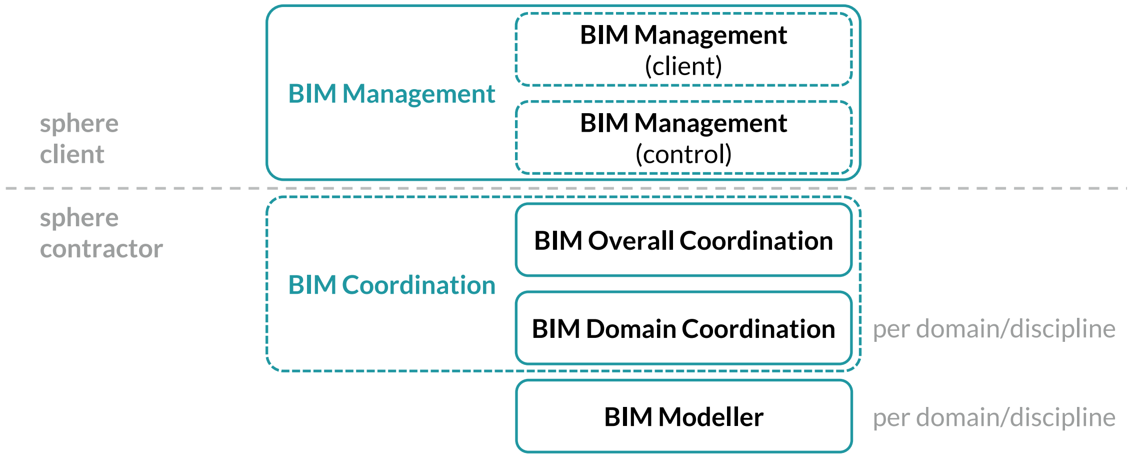


Fig. 2.15: Example of possible BIM organisational structure (BIM roles)

BIM Domain Coordination (sphere of the contractor): It verifies domain-specific *openBIM* content of its own domain in proactive coordination with the other *BIM Domain Coordinations*. Among other things, it is responsible for providing the *BIM Overall Coordination* with the domain model in verified form (including the verification reports), managing BCF comments related to itself, ensuring the conformity of the domain model and design documents, and performing model-based evaluations (e.g. for cost estimation) from its own domain model.

VDI 2552 Part 2 also defines the information management roles of BIM author (modeller) and BIM user. BIM author is a project member who creates and edits model content. BIM user describes a project member who only uses the models to obtain information and does not add any data or information to the models.

The aim of the organisational structure is to define clear points of contact, clear lines of decision (responsibility), and a clear distribution of tasks (roles, authority, and scope of each task). This is important for good information management.

Collaboration requires an assessment of the BIM competence of all project participants over project life cycle. The client (appointing party) must analyse the BIM competence (qualification) of the project participants. ISO 19650-1 calls this the *capability and capacity review* of the *delivery team. The appointing party (usually the client) should review the capability and capacity of the* (prospective) *delivery team (the project participants). Capability refers to the ability to perform a given activity (e.g. through the necessary experience, skill, or technical resources) and capacity refers to the ability to complete an activity in the required time.*

The BIM competence (qualification) of the organisational units should be ensured at the start of the project by querying their competencies to identify potential competence deficits and to define training requirements. Only then can project responsibilities be defined. *BIM Management (control)* 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.

2.5.2 BIM implementation documents

They form the basis of BIM projects. BIM implementation documents explain the relevant objectives of the client, the requirements for the project participants, and the procedures for successfully implementing these requirements. They also specify any supplements to the common project manuals, e.g. the organisation manual or project manual.

The use of BIM implementation documents is strongly recommended, although not (yet) mandatory, for projects of any size and complexity. BIM implementation documents provide a clear regulation of the project organisation, project objectives, project execution specifications, project management, definition of collaboration, and quality assurance for BIM projects. These provisions are often missing from standard project manuals. BIM implementation documents (such as EIR) also help clients to identify what information is required to achieve their project objectives.

Examples of currently established and freely available BIM implementation documents are EIR and BEP (see QR codes) from buildingSMART Austria.

The individual BIM (implementation) documents are:
Asset information requirements AIR: The AIR defines the operator’s long-term asset data structure and detail requirements based on data management. It identifies 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 *exchange information requirements EIR*.

Project information requirements PIR: The PIR relate to the requirements of the delivery phase (design and construction). They are required to respond to the overall strategic objectives in relation of a specific project.

The AIR and the PIR therefore determine the content, structure and methodology of the AIM (Asset Information Model) and the PIM (Project Information Model). Both the AIR and the PIR provide input to the *exchange information requirements EIR*.

Exchange information requirements EIR: The EIR is the concrete description of the client’s information needs and is therefore described as a requirement for a contractor. In accordance with ISO 19650, it defines the business, commercial, and technical aspects of producing project information (e.g. information standards). The technical aspects of the EIR should contain the detailed information required to fulfil the PIR. It serves as the basis for the BEP in the respective project. In particular, the client’s EIR contains the BIM requirements, BIM processes, BIM service specifications, standards to be met, and BIM applications to achieve the client's BIM objectives.

General information on Exchange Information Requirements EIR
In accordance with ISO 19650, the *Exchange Information Requirements EIR* are used for the definition of requirements for the information exchange between the *appointing party* and the *appointed party*. There are different *appointing parties* at different levels in a project, e.g. the *client*, the *lead appointing party*, *other appointing parties*. The *lead appointing party* has to fulfil the *EIR* of the *client* and can subdivide these EIR and pass it on to sub-partners. The *(lead) appointing parties* can also augment the received EIR with their own EIR.

At the top level is the *client's exchange information requirements* for the entire project. In the past, this EIR document was called »*Employer Information Requirements*«. This term is still in use in Austria and Germany for the (in German: »*Auftraggeber-Informationsanforderungen AIA*«). In Switzerland, the terms of the ISO 19650 series are used, and the document is referred to as »*Exchange Information Requirements*«.
To avoid confusion between the information exchange requirements (at the different levels), the term »*Client's* **EIR**« is used in the BIMcert Handbook when referring to the EIR document at the top level (of the *client*).

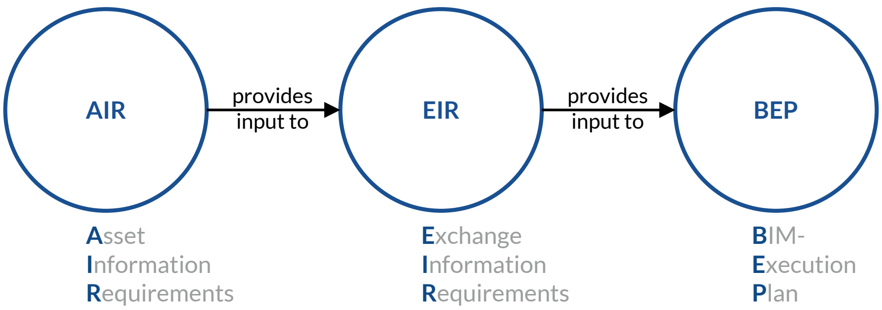


Fig. 2.16: Influence of AIR on EIR and on BEP

BIM Execution Plan BEP: According to ISO 19650-2, the *BEP* explains how the *information management aspects of the appointment* are carried out by the *delivery team*. The *BEP* is therefore a *guidance document* that defines the basis for BIM-based collaboration. It defines the organisational structures and responsibilities. Roles and responsibilities can be assigned in a responsibility matrix. The *BEP* provides the framework for the BIM services and defines the processes/workflows and the collaboration requirements for each participant (e.g. responsibilities). The models and processes are standardised in terms of structures (e.g. spatial structure or model structure), elements, and information. The *BEP* also specifies the project-related characteristics and defines the level of information and detail as well as their quality. It is prepared by the project team and updated during the project (responsibility lies with the *BIM Overall Coordination*, the *lead appointed party*). Changes require the approval of the project team (e.g. through the individual *BIM Domain Coordination*). A well-drafted *BEP* improves the design process and communication within the project team. The *BEP* should become part of the contract between the *client* and the project participants. The client specifications for the *BEP* are the *Client's EIR* and any *preBEP* provided, which corresponds to a *project-specific model BEP*, specifying the requirements from the *Client's EIR* and containing the specified structure.

The *AIR* are hierarchically above the *EIR* – their requirements feed into the *EIR*. Using the *AIR*, the EIR specify the *client's information requirements*. 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 through the completion of construction or handover to operation and should be updated as the project progresses.

The topics of the EIR and BEP include:

- **project information:** summary of the client's content requirements (e.g. dates/ milestones for the information transfer),
- **general specifications:** 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 the 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 LOG and LOI definitions).

Important: The *EIR* defines the content of the subject areas, and the *BEP* formulates these specifications. For example, the *BEP* (in accordance with 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 the quality control. At the beginning of the project, a review of the *EIR* and *BEP* should be held with all key project participants. At this meeting, the content and scope of the tasks are explained and agreed upon. Such a review meeting promotes successful cooperation in the project. The *BIM Management (control)* can use the review to check the participant's level of knowledge on the topics of an openBIM project.

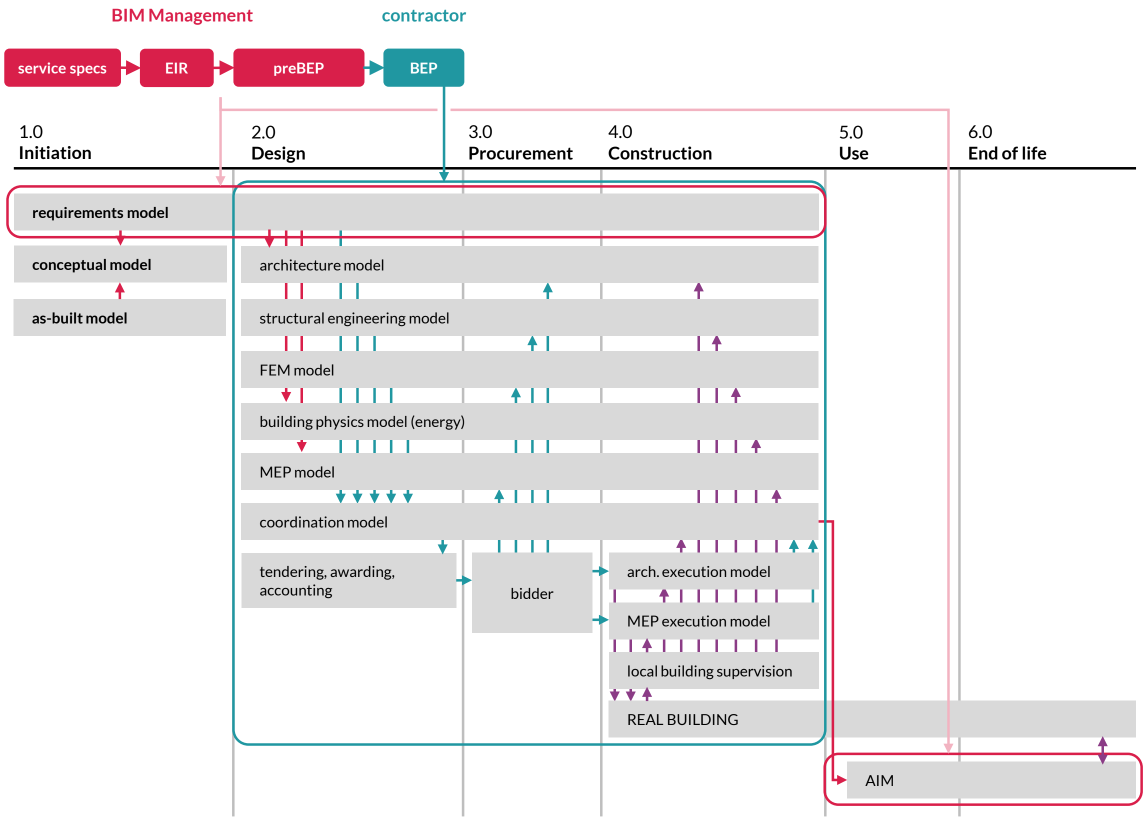
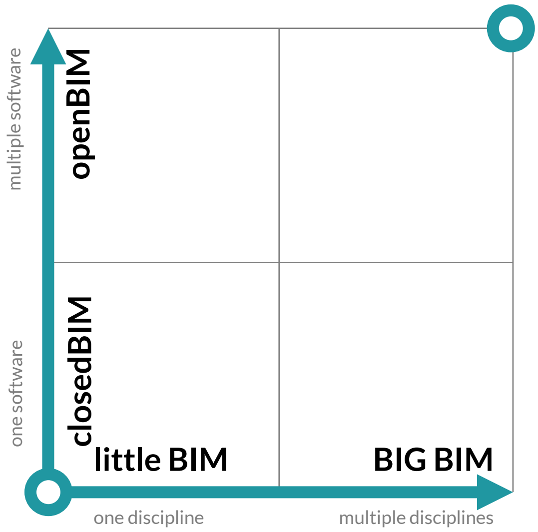


Fig. 2.17: Development of the models during the phases of a project (phases according to EN 16310)

2.5.3 openBIM collaboration

The development stages of BIM provide a clear classification in this respect (see Fig. 2.18). The free choice of software supports the use of the most suitable software for the respective task (best practice). 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 following advantages arise:

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



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

Fig. 2.18: BIM development stages

The application of the *openBIM* method is also promoted by standardisation. National standards create additional foundations for a comprehensive, uniform, product-neutral, and systematised exchange of graphical data and the associated factual data on the basis of IFC and bSDD.

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

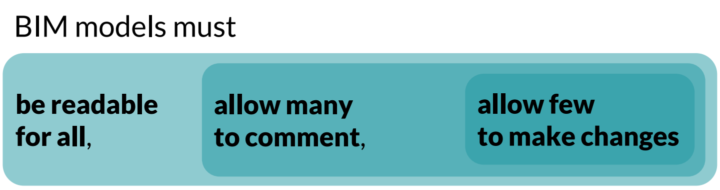


Fig. 2.19: Requirements for BIM models

Model-based collaboration not only concerns quality management in the overall model, but also (first) collaboration at model level. According to **openBIM**, every domain planner who supplies model data creates it in its own software application (authoring software) as a domain model. Due to the size of the data, 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.

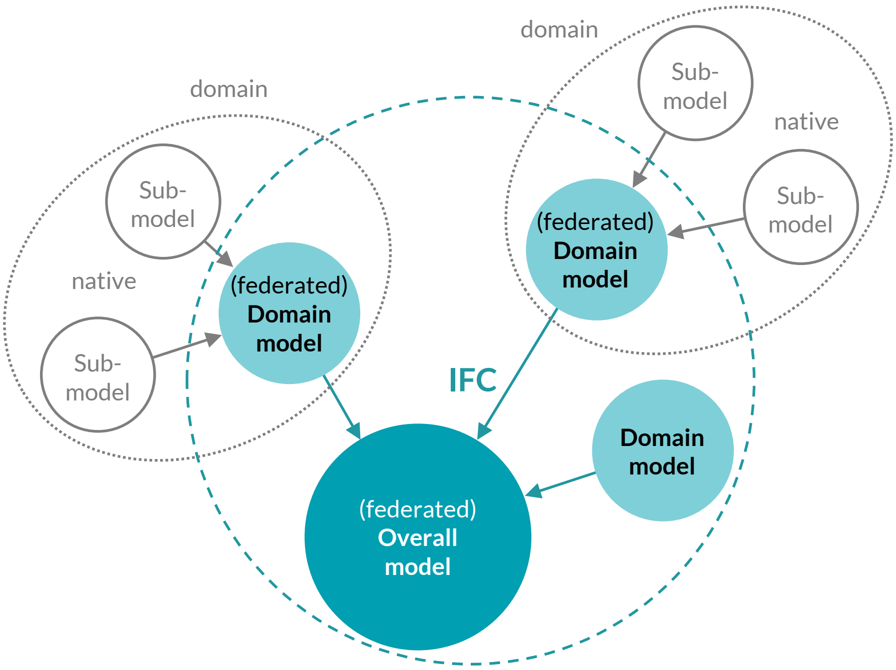


Fig. 2.20: Collaboration in an openBIM project

In contrast, there is 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). This checks and evaluates the model data independently. Communication takes place digitally. Problem points are always transmitted in report form. This is done in PDF format 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 (PDF and BCF) takes place via the CDE provided for this purpose.

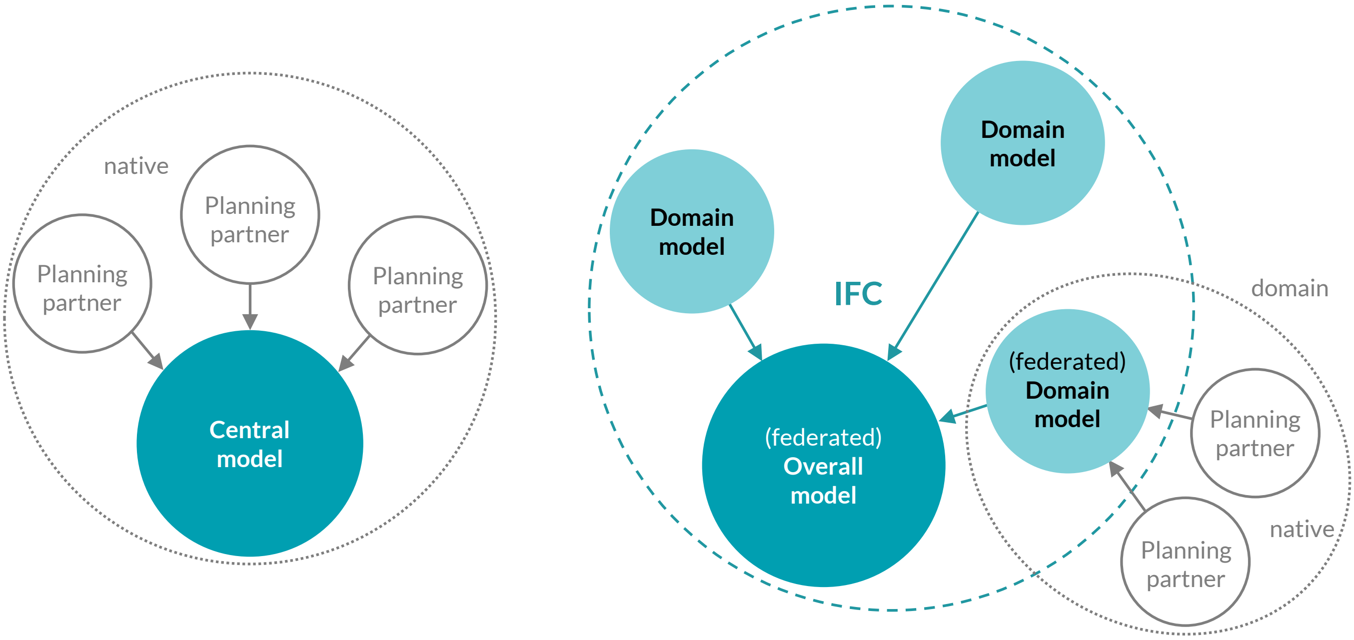


Fig. 2.21: Collaboration in a closedBIM project (left) or a hybrid of closedBIM and openBIM (right)

3 Advanced knowledge

This chapter provides an in-depth look at the various *openBIM* standards developed by buildingSMART. These new *openBIM* terms – especially the acronyms – are a big challenge, especially for newcomers. A good understanding of these terms is essential for the full use of *openBIM*. The content of this chapter forms the basis for the descriptions of *openBIM* project implementation in Chapter 4.

Fig. 3.1 and Fig. 3.2 put the terms into context. Unlike the overview illustrations in Chapter 4, this illustration does not show the entire *openBIM* process within a project, but only from the perspective of modelling. For more detailed information, please refer to the individual Sections.

The planning professional receives the model requirements (including LOIN, Section 3.6) via the *BIM Execution Plan (BEP)* and begins to implement them in their native software. Before starting the actual creation of the domain model, the *first step* is to create the new classifications (if allowed by the software policy) and the necessary properties in the software. In the *second step*, these are mapped (for IFC export) to the IFC data schema or MVD (Section 3.2 and Section 3.3). This is followed by the creation of the domain model according to the modelling guidelines (Section 3.1.3). 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 must be carried out manually by each project participant in the respective native software; this is inefficient and error-prone.

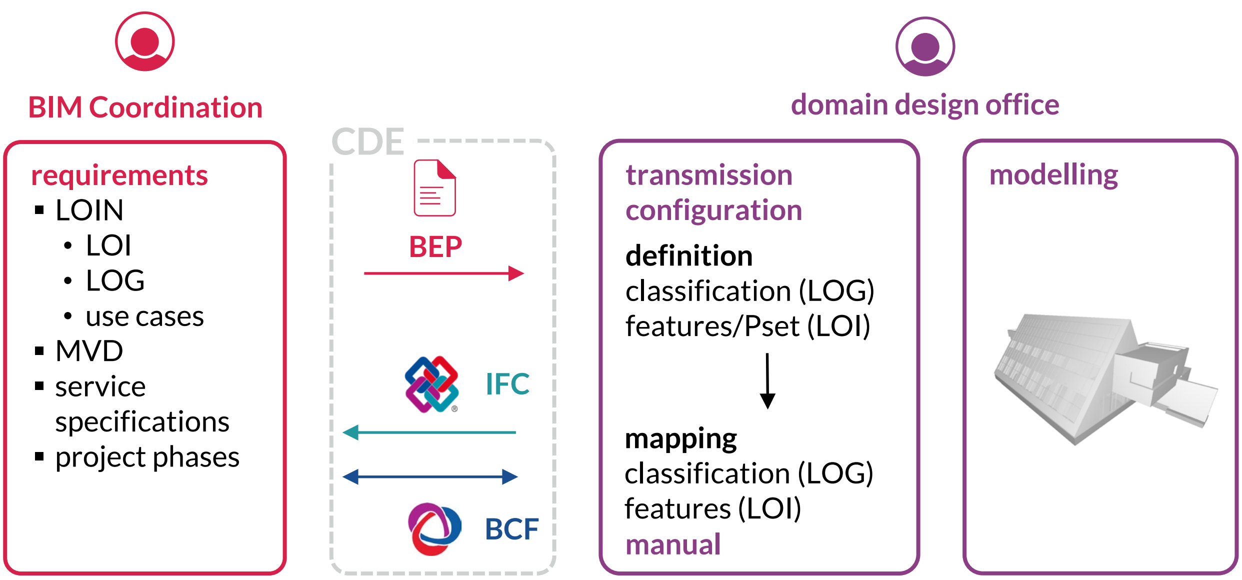


Fig. 3.1: Manual management of properties and classifications

An improved method is to use a data structure tool (Section 2.3.3) that centralises the definition and mapping of classifications and properties/property sets (Section 3.2.3) for multiple software products and the IFC data schema or MVD (Section 3.2 and Section 3.3). At the same time, these are linked to the service specifications (Section 2.5), project phases, and *use cases* (Chapter 4) in a database. In addition, classifications and properties from the bSDD (Section 3.8) can be directly integrated using an API. The results are software-specific templates or the IDS standard (Section 3.7), which can be imported directly into the software if the software supports the standard. 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 organisation. The client may provide the data structure tool centrally and/or each actor may use their own data structure tool.

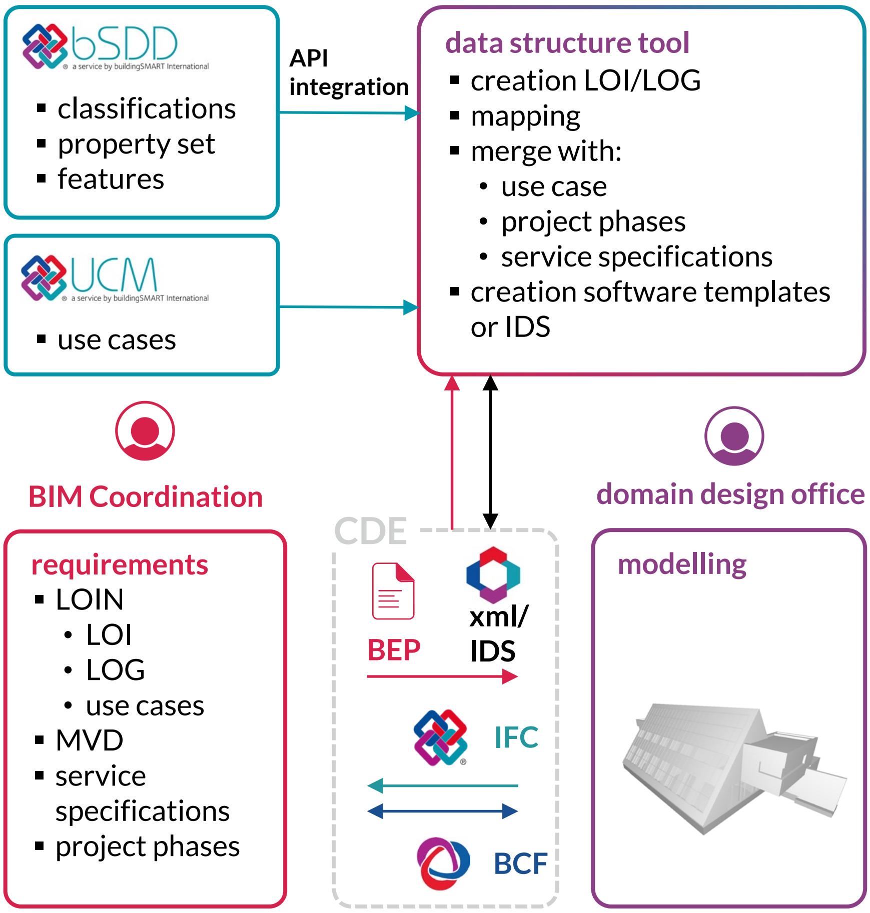


Fig. 3.2: Using data structure tools to manage model information requirements

Some sources and recommended reading for Chapter 3

Borrmann A., König M., Koch C., and Beetz J. (Hrsg.): »*Building Information Modeling: Technologische Grundlagen und industrielle Praxis*«. Zweite, aktualisierte Auflage, Springer Fachmedien, Wiesbaden, 2021, ISBN: 978-3-658-33361-4 (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. (2. Edition expected in 2024, see QR code)

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

3.1 Standardisation

This section provides an overview of the main *openBIM* standards and their development at national, European, and international level. The standards mentioned in Chapter 2 are expanded with additional standards and placed in context with each other.

Fig. 3.3 shows the dependencies of the various standards in chronological order. The basis for the use of *openBIM* is the manufacturer-neutral data structure IFC4, which was developed by bSI and first certified in 2013 as the ISO standard ISO 16739 »*Industry Foundation Classes (IFC) for data exchange in the construction industry and asset management*« (since 2018: ISO 16739-1). In 2024, ISO 16739-1 will be updated to include IFC 4.3.

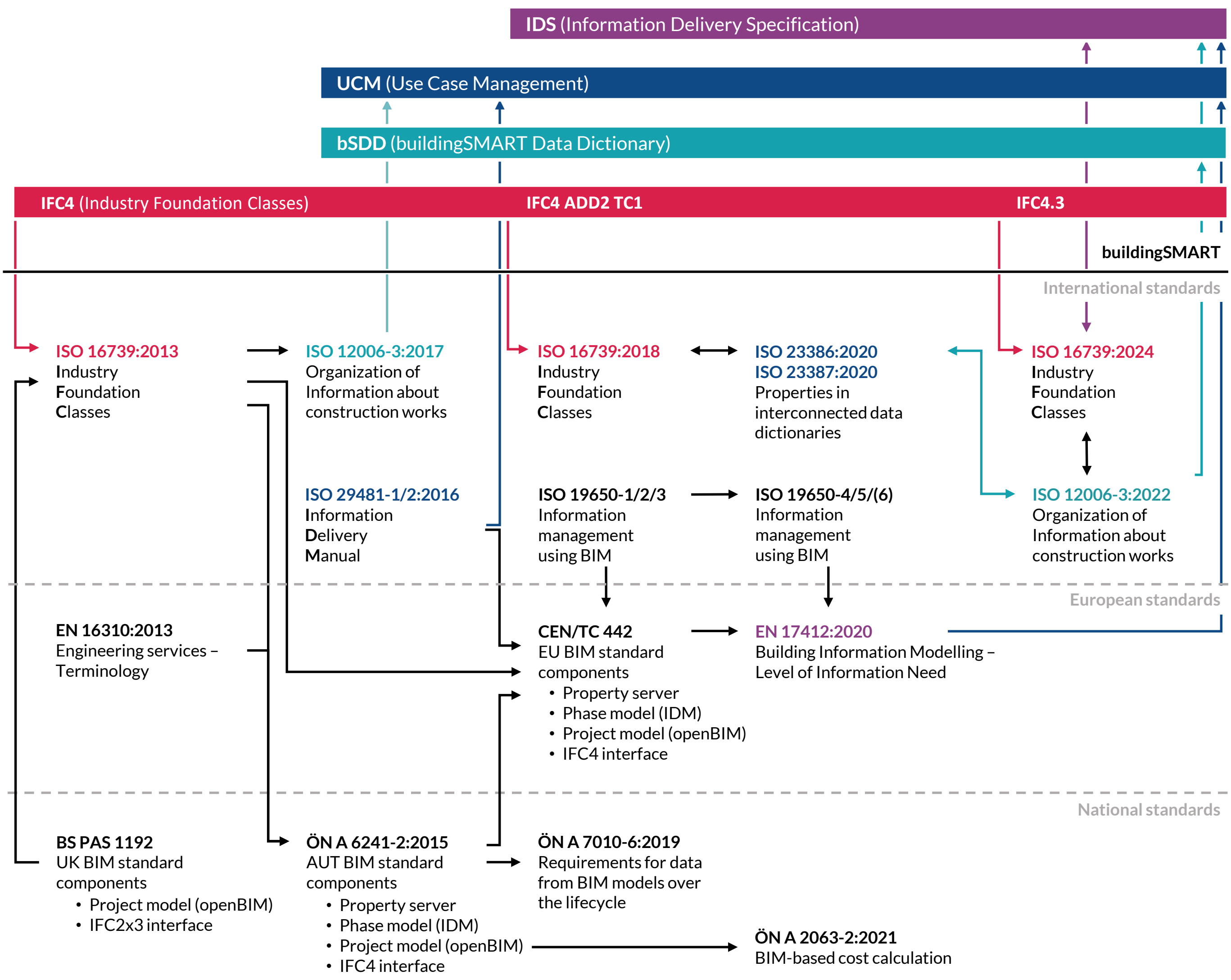


Fig. 3.3: Overview of standardisation

IFC forms the data structure for the exchange of geometric and non-geometric (alphanumeric) information. This alphanumeric information is primarily transported via IfcPropertySet. Standard IfcPropertySet definitions are contained in ISO 16739. buildingSMART also provides these as a separate specification. They are managed in the international property server bSDD, which is based on ISO 12006-3 »Organisation of data on buildings«. ISO 23387 defines the interaction between IFC, bSDD, and digital product data (data sheet) – their composition is in turn defined by ISO 23386.

Now that the information structure has been standardised, the question arises: In what form should the data be output by the software? This is defined using Model View Definition (MVD), with which the software is certified by bSI. MVDs are developed using the Information Delivery Manual (IDM). In an IDM, process representations are used to 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 the data structure and data exchange is the standardisation of information management with BIM in the ISO 19650-1/2/3 standards. ISO 23387 defines the interaction of IFC, bSDD, and digital product data (*Data Templates*) – their composition is in turn defined by ISO 23386.

Fig. 3.3 also shows the influence of IFC4 standardisation and the standardisation of a uniform classification of planning services in EN 16310 on national BIM standards, such as ÖNORM A 6241-2. EN 16310 also influenced the European working group for BIM »CEN/TC 442«, which aims to develop a harmonised European *openBIM* standard. With EN 17412-1, CEN/TC 442 has already published the standardised LOIN definition (mentioned above). In contrast to various national BIM standards, the publications of CEN/TC 442 have a significantly increased importance for the software industry, as they represent the requirements of a much larger market.

3.1.1 International standards

ISO 16739:2013, ISO 16739-1:2018/2024

As an independent organisation, bSI develops its own standards. The best known of these is IFC, which enables the cross-software exchange of modelling information. The IFC4 version was officially published in March 2013 as ISO 16739 and is constantly being developed further. IFC4.3 has also been an ISO standard since 2024.

ISO 12006-3:2022

bSDD exists in addition to the IFC data structure. This is a web-based service for creating and consolidating customised data structure additions (ontologies) based on ISO 12006-3, which defines the IFD (International Framework for Dictionaries). The IFD is a framework for defining classification systems. The basic principle is that all concepts can have a name and a description (regardless of the language). Only a unique identification code is relevant for identification and use. By contracting labels in several languages to the same concept, a multilingual dictionary is created.

ISO 29481-1/2

The IDM methodology is described in ISO 29481-1/2. This supports the description of information requirements in connection with the processes within the life cycle. MVDs and use cases are developed based on this IDM.

ISO 19650-1/2/3/4/5(/6)
ISO 19650-1/2/3/4/5(/6) contain process specifications that define BIM services and their implementation. Part 1 contains the description of terms and principles. Part 2 describes information management in the planning, construction, and commissioning phases. Part 3 includes the operating phase of the assets. Part 4 describes the information exchange and Part 5 the specification for safety aspects of BIM, digitised buildings, and smart asset management.

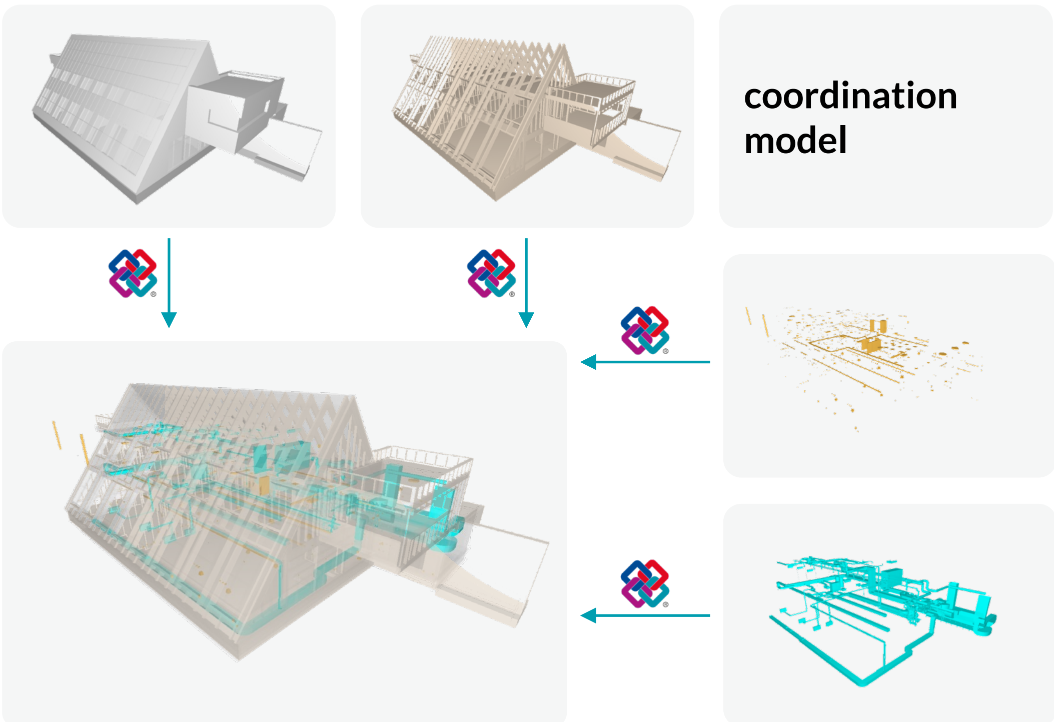


Fig. 3.4: Coordination model as a federated model

3.1.2 European standards

In 2015, the standardisation committee CEN/TC 442 »Building Information Modeling (BIM)« was founded at European level. The committee is to develop a structured series of standards and reports. The aim is to determine the methodology for defining, describing, exchanging, monitoring, and recording asset data, as well as the secure 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«
- »Exchange Information«
- »Information delivery specification«
- »Data dictionary«

EN 17412-1
EN 17412-1 is a European standard that deals with the level of information need (LOIN) of Building Information Modelling (BIM). It sets out the concepts and principles for defining information needs and information delivery using BIM. This standard is important for defining the level of detail and scope of information required based on use cases that are exchanged and delivered throughout the lifecycle of buildings (see Section 3.6).

EN 16310:2013

At European level, EN 16310 was published in 2013. This standard deals with the standardised classification of planning services. This document defines terms relating to engineering services. A harmonised glossary of key terms from the construction industry at European level is intended to promote free competition in the EU. At the same time, it is intended to reduce problems in cross-border co-operation resulting from different interpretations of relevant terms in the various European countries. The focus is on the entire engineering services sector (construction of buildings, infrastructure, and industrial plants). The life cycle of construction facilities is divided into several phases/stages, which are subdivided into sub phases / sub stages (see Fig. 3.5). These phases are compared with phases from other countries and standards in Chapter 4 (Fig. 4.3 and Fig. 4.4).

		Stages	Sub Stages
Before use stage	Product stage	**0. Initiative**	0.1 Market study 0.2 Business case
		1. Initiation	1.1 Project initiation 1.2 Feasibility study 1.3 Project definition
		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
		3. Procurement (IF)	3.1 Procurement 3.2 Construction contracting
	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

Fig. 3.5: Phases / stages of a project / asset according to EN 16310

3.1.3 Standards in Austria

ÖNORM A 6241-2

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

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

The ASI summarises the content of its standards as follows:

ÖNORM A 6241-1 regulates the technical implementation of data exchange and data storage of building information for structural engineering and related space-forming civil engineering structures required during the planning and 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 visualisation principles. It specifies the basic techniques for data transfer of two-dimensional CAD files and for »Building Information Modeling« (BIM).

ÖNORM A 6241-2 regulates the technical implementation of a uniform, structured, multidimensional data model for buildings and related, space-creating structures 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 based on 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.

ÖNORM A 6241-2 was published before ISO 19650-1. As a result, the terms are different between the standards. The terms according to ISO 19650-1 are therefore shown in brackets to the respective term from ÖNORM A 6241-2 when they are mentioned for the first time. Section 7 »Level of detail« in ÖNORM A 6241-2 is currently being revised. The first section of the standard defines general terms. This is followed by a description of the project model (ISO 19650: project information model). A project model is created based on the client's requirements (EIR). This project model consists of partial models (domain models), which can be divided into sub-models (see Fig. 3.6).

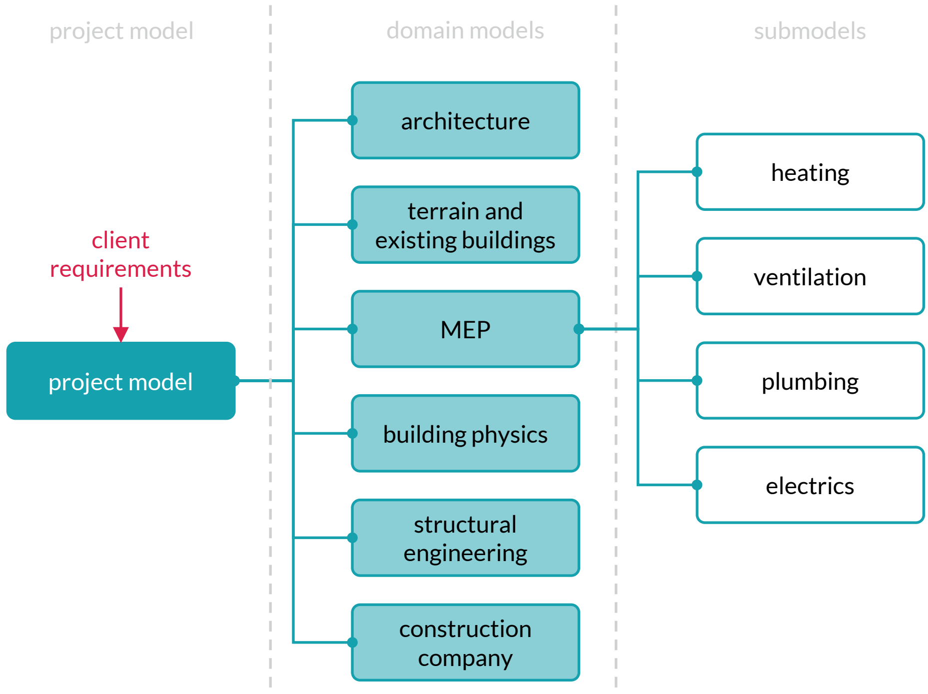


Fig. 3.6: Representation of a project model

The level of detail depends on the respective life cycle phase of a building. These life phases were defined in accordance with ÖNORM EN 16310, which are compared in »Appendix B Assignment of life phases«. Appendix C describes the exact level of detail according to the life cycle phase of a building.

The description of the billing of services is of great importance for the tender and award process. The standard expressly points out that billing can be carried out using models and not according to the work contract standards – if this is contractually agreed in advance. The term *dimension* is also introduced in ÖNORM A 6241-1. This is intended to describe the handling of the virtual building model data in a project based on the factors of time, costs, and sustainability:

- **3D – building model:** presence of geometric and alphanumeric information in a building model.
- **4D – time:** construction schedule determined/simulated based on the model information.
- **5D – costs:** quantities and costs are determined semi-automatically using the standardised service descriptions in accordance with ÖNORM A 2063. ÖNORM A 6241-1 expressly points out that quantities do not have to be determined in accordance with work contract standards. If there is an agreement between the client and the contractor, the quantities can be determined according to the model.
- **6D – sustainability:** assessment regarding environmental, social, and economic issues based on model information.

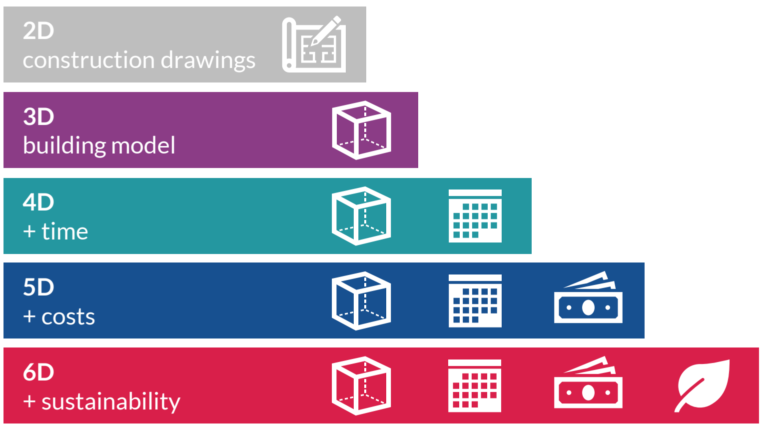


Fig. 3.7: Dimensions according to ÖNORM 6241-2

The ASI property server is described in ÖNORM A 6241-2. This is a type of national property server. The definition of properties including description, discipline, type, project phase etc. is carried out in the ASI property server. These properties are linked to the international property server (bSDD) using the bSDD-URI.

The last section of the standard describes the IFC data schema (then still IFC2x3) as the software manufacturer-independent standard for the exchange of information in the construction industry. The annex also contains a rudimentary modelling guide.

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

ÖNORM A 2063-2
ÖNORM A 2063-2 is a technical standard that deals with the exchange of data in electronic form for the tender, award, and invoicing (procurement) phases, in particular considering the Building Information Modeling (BIM) planning method. This standard specifies the structure of data structures that are exchanged automatically between various parties involved in the construction process. ÖNORM A 2063-2 covers specific areas such as element lists (procurement elements) and parameter lists. The element list serves as a link between the service items and the IFC model.

3.1.4 Standards in Switzerland

At the present time (spring 2024), the following standards are available in Switzerland in connection with the application of the BIM method:

SIA 2014 – CAD data exchange – Layer structure and layer key
Structure and exchange CAD data in a standardised form.

SIA 4013 – CAD data exchange guidelines – Organisation and planning
Establishment of a regulation for CAD data exchange in the so-called CAD project manual.

SIA 405 – Geodata on supply and disposal lines
Basis for the derivation of a cross-media line cadastre from various plant information of the individual plant information models.

SIA 4008 – Pipeline cadastre – Guide to standard SIA 405
The guide serves as an application aid for the standard and contains additional thematic explanations.

SN EN ISO 19650
The following standards cover the organisation and digitisation of information on buildings and engineering services, including building information modelling (BIM) – (Information management with BIM):

- SN EN ISO 19650-1:2018: Part 1: Concepts and principles
- SN EN ISO 19650-2:2018: Part 2: Delivery phase of the assets
- SN EN ISO 19650-3:2020: Part 3: Operational phase of the assets
- SN EN ISO 19650-4:2022: Part 4: Information exchange
- SN EN ISO 19650-5:2020: Part 5: Security-minded approach to information management

3.1.5 Standards in Germany

The Verein Deutscher Ingenieure e.V. (VDI) (Associations of German Engineers) publishes numerous guidelines on the subject of BIM:

VDI 2552 Part 1 (2020) »Building Information Modeling — Fundamentals«
VDI 2552 Part 2 (2022) »Building Information Modeling — Terms and Definitions«
VDI 2552 Part 3 (2018) »Building Information Modeling — Model-based quantity determination for budgeting, time scheduling, contracting and accouting«
VDI 2552 Part 4 (2020) »Building Information Modeling — Requirements for data exchange«
VDI 2552 Part 5 (2018) »Building Information Modeling — Data management«
VDI 2552 Part 6 (2023) »Building Information Modeling — Facility management«
VDI 2552 Part 7 (2020) »Building Information Modeling — Processes«
VDI/bS-MT 2552 Part 8.1 (2019) »Building Information Modeling — Qualifications — Fundamental knowledge«
VDI/bS-MT 2552 Part 8.2 (2022) »Building Information Modeling — Qualifications — Advanced knowledge«
VDI/bS-MT 2552 Part 8.3 (2022) »Building Information Modeling — Qualifications — Skills«
VDI 2552 Part 9 (2022) »Building Information Modeling — Classification systems«
VDI 2552 Part 10 (2021) »Building Information Modeling — Employers information requirements (EIR) and BIM execution plan (BEP)«
VDI/bS 2552 Part 11.1 (2021) »Building Information Modeling — Information exchange requirements for BIM use cases«
VDI/bS 2552 Part 11.2 (2022) »Building Information Modeling — Exchange requirements — Slots and openings«
VDI/bS 2552 Part 11.3 (2020) »Building Information Modeling — IExchange requirements — Formworks and scaffolding systems (in-situ concrete)«
VDI/bS 2552 Part 11.5 (2023) »Building Information Modeling — Information exchange requirements — Elevator technology«
VDI/bS-EE 2552 Part 11.8 (2023) »Building Information Modeling — Exchange requirements — Factory planning«
VDI/DIN-EE 2552 Part 12.1 (2020) »Building Information Modeling — Structural description of BIM use cases«

3.2 IFC – Industry Foundation Classes

This section gives a detailed description of the structure of IFC – an essential basis for the exchange of digital building information. Industry Foundation Classes (IFC) is an open international standard for the exchange of Building Information Modeling (BIM) data, forming the basis for the application of openBIM. The standard comprises standardised declarations and properties for elements that are necessary to describe buildings and their associated technical equipment over their entire life cycle. In addition, IFC4.3 extends the scope of data definitions to include transport infrastructure facilities (road and rail).

IFC specifies a data schema and a file format. It is standardised in ISO 16739–1 and includes:

- IFC data schema,
- documentation (HTML text, see QR code),
- definition of/for property sets and quantity sets, and
- mechanisms for exchaning and serialising files (= schemas such as EXPRESS and XSD for storing data in files).

At the beginning of this section a detailed distinction between the data schema, the file format, and the actual file is provided, laying the foundation for a deeper understanding of the subsequent content. The architecture of the data schema is described, with a particular focus set on basic modelling concepts such as conceptual *layers*, inheritance hierarchies, and domains. Based on this, a precise description of the structure of an IFC file is given, using a STEP file in accordance with the IFC data schema. The various *entities*, the spatial structure of buildings, the representation of relations and the use of *properties* are discussed. The aim is to provide a holistic picture of the structured and systematic organisation and application of the IFC data schema.

3.2.1 Overview of data schema, file format, and file

IFC is both a data schema and a file format (.ifc) that is used to transfer building data. Although, the previously named terms have different meanings, they are often confused with each other in practice. This section explains the differences between them. Detailed descriptions of the data schema and the file format can be found in Section 3.2.2 and Section 3.2.3, respectively. A data schema is a formal description of the structure of data. IFC as a data schema defines a structure for both geometric and alphanumeric information. It can be thought of as a »blueprint« for various element entities (e.g. IfcWall, IfcSite, etc.) that have both geometric and text-based properties. Furthermore, it also contains the relations (relations) between the entities. The textual description of the data schema is documented by buildingSMART (see QR code). This complete documentation (HTML) is also part of ISO 16739-1.

The import and export of IFC files in a BIM application does not usually include the entire ISO-standardised IFC data schema. The IFC schema is designed to be flexible to the point that it enables many different configurations. An example thereof is given as follows: A wall can be represented in different ways, either as a line segment between two points or as a 3D geometry for visualisation and analysis (e.g. extruded solids or triangulated surfaces). The capabilities of a BIM software application regarding the IFC data schema are governed by so-called Model View Definitions (see Section 3.3). MVD thus specify and reduce the data schema according to the respective requirements of exchange scenarios.

BIM users usually encounter IFC files when they export, import, or check models as IFC. These IFC files are structured according to the respective file format, containing entities as defined by the IFC data schema. The IFC standard is based on several existing technologies (see Section 1.2), which is why various underlying data modelling languages and applicable file formats are described in the IFC scope of definition. By far the most common file format is the STEP Physical File in accordance with ISO 10303-21. The file extension is .ifc and can be opened and read with a standard text editor. The structure is described by the data modelling language EXPRESS, which is regulated in Part 11 of the STEP standard (ISO 10303-11). In addition to the textual notation, the standard defines a graphical notation, EXPRESS-G, to represent the data. The documentation of the IFC4.3 data schema contains illustrations using EXPRESS-G. Various file formats are offered for the exchange of specific model data. The STEP Physical File is also available in a compressed version, zipping an IFC file using a ZIP file. In this case, the file extension is .ifczip. Other options include the use of XML instances (extension .ifcXML). The structure of the XML file is defined as an XML Schema Definition (XSD for short). All file formats are based on the same IFC data schema, with the representation of the data depending on the respective file format.

In summary, the IFC data schema describes the structure and relation of geometric and alphanumeric data as well as their semantics. It comprises standardised declarations (element entities – e.g. IfcWall, IfcBuilding) as well as the respective associated standardised specifications for their alphanumeric (property sets and properties) and geometric description. It also contains options for describing relations between elements. Based on this description in the data schema, the information for a building (geometric and alphanumeric information) is contained in the respective format, with the STEP format (file extension .ifc) being the most commonly used.

An important note for understanding: Some entities described in the IFC data schema (e.g. IfcRoot, IfcElement) are used to organise subordinate entity definitions and do not appear in the actual file (e.g. .ifc, .ifcxml). These are so-called abstract entities.

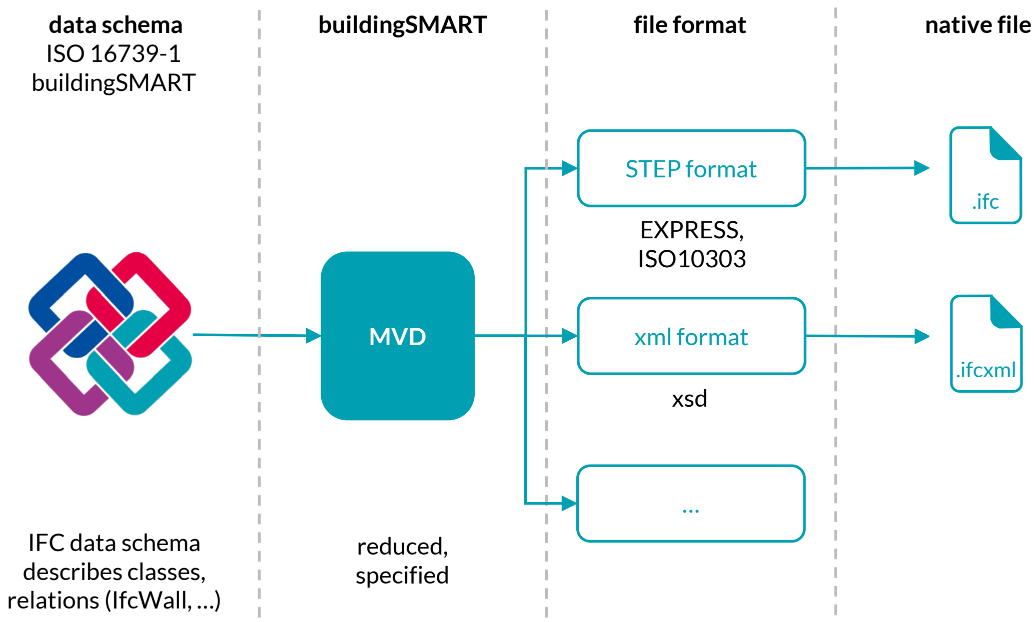


Fig. 3.8: Relationship between IFC data schema, file format, and file

Example data schema, file format, and file

Exemplary for the entity wall (IfcWall), Fig. 3.9 and Fig. 3.10 show how the IFC data schema is linked to the file using STEP (.ifc) and XML (.ifcxml) file formats, respectively. The documentation of the IFC data schema in accordance with ISO standard 16739-1 is depicted in the upper section of Fig. 3.10, listing the required attributes for an IfcWall in the STEP format. The lower part of the image shows the file section of a wall in STEP file format, including the link to the IFC data schema. The IFC data schema is a specification that defines which information must be contained in the respective file formats. In addition, the extract from the .ifc file illustrates the main advantage of the IFC format over conventional native formats: The data in the .ifc file is unencrypted and can therefore be read with any word processing software (e.g. in a text editor).

Fig. 3.9 shows the same data information for the same wall as Fig. 3.10, but in XML format. The structure of this data is defined by an XSD file (XML schema definition), which serves as a template for the XML format.

```
<IfcWall id="i1897">
  <GlobalId>2C45vBrGbB_w_CB97snkya</GlobalId>
  <OwnerHistory>
    <IfcOwnerHistory xsi:nil="true" ref="i1648"/>
  </OwnerHistory>
  <Name>WandBeispiel-001</Name>
  <ObjectType>NOTDEFINED</ObjectType>
  <ObjectPlacement>
    <IfcLocalPlacement xsi:nil="true" ref="i1802"/>
  </ObjectPlacement>
  <Representation>
    <IfcProductDefinitionShape xsi:nil="true" ref="i1885"/>
  </Representation>
  <Tag>8C105E4B-D509-4BFB-AF8C-2C91F6C6EF24</Tag>
  <PredefinedType>notdefined</PredefinedType>
</IfcWall>
```

Linking to element ref=i1648

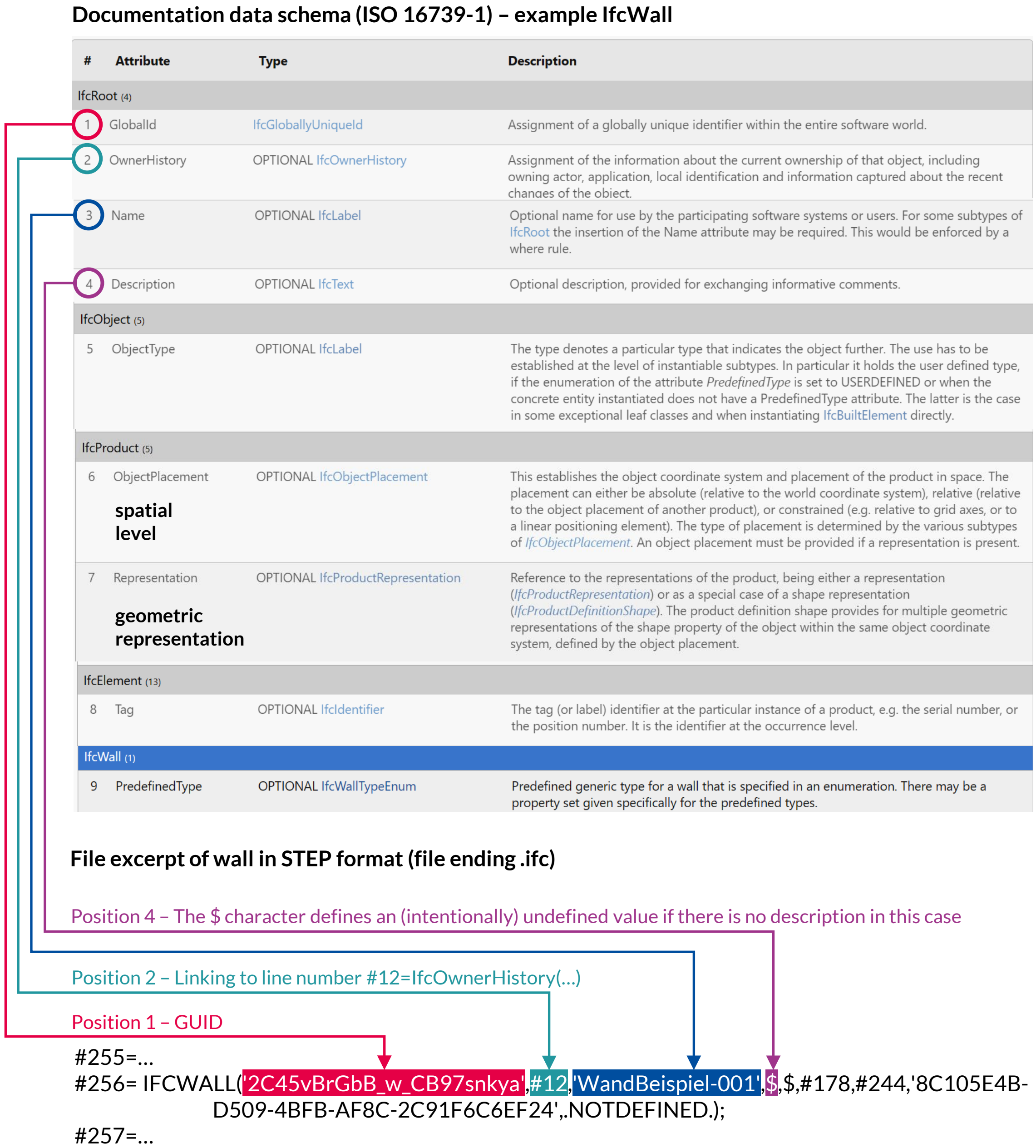
Fig. 3.9: File excerpt for a wall in XML format (file extension .ifcxml)

3.2.2 Basics of IFC data schema

This section provides an insight into the development of IFC (in addition to Section 1.2), its underlying data modelling language, and the structure of the data schema.

3.2.2.1 Development and versioning of IFC

In the 1980s, the standardisation framework »STEP – Standard for the Exchange of Product model data« was defined for the first time in the ISO 10303 standard to create uniform interfaces between heterogeneous CAD systems. In the mid-1990s, a group of engineering firms, construction companies, and software manufacturers, including Autodesk, Bentley, and Nemetschek, came together to form the International Alliance for Interoperability (IAI), which was later renamed »buildingSMART«. Their aim was to make standardisation in the construction industry more efficient. In 1996, buildingSMART published the first version of the Industry Foundation Classes: IFC1.0. Software manufacturers implemented



Documentation data schema (ISO 16739-1) – example IfcWall

#	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.
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.
4	Description	OPTIONAL IfcText	Optional description, provided for exchanging informative comments.
IfcObject (5)			
5	ObjectType	OPTIONAL IfcLabel	The type denotes a particular type that indicates the object further. The use has to be established at the level of instantiable subtypes. In particular it holds the user defined type, if the enumeration of the attribute *PredefinedType* is set to USERDEFINED or when the concrete entity instantiated does not have a PredefinedType attribute. The latter is the case in some exceptional leaf classes and when instantiating IfcBuiltElement directly.
IfcProduct (5)			
6	ObjectPlacement **spatial level**	OPTIONAL IfcObjectPlacement	This establishes the object coordinate system and placement of the product in space. The placement can either be absolute (relative to the world coordinate system), relative (relative to the object placement of another product), or constrained (e.g. relative to grid axes, or to a linear positioning element). The type of placement is determined by the various subtypes of *IfcObjectPlacement*. An object placement must be provided if a representation is present.
7	Representation **geometric representation**	OPTIONAL IfcProductRepresentation	Reference to the representations of the product, being either a representation (*IfcProductRepresentation*) or as a special case of a shape representation (*IfcProductDefinitionShape*). The product definition shape provides for multiple geometric representations of the shape property of the object within the same object coordinate system, defined by the object placement.
IfcElement (13)			
8	Tag	OPTIONAL IfcIdentifier	The tag (or label) identifier at the particular instance of a product, e.g. the serial number, or the position number. It is the identifier at the occurrence level.
IfcWall (1)			
9	PredefinedType	OPTIONAL IfcWallTypeEnum	Predefined generic type for a wall that is specified in an enumeration. There may be a property set given specifically for the predefined types.

Fig. 3.10: IFC data schema and STEP data schema

the standards in their products, which buildingSMART published free of charge and vendor-neutral, independent of ISO certifications. In 2007, version IFC2x3 TC1 was released, which was ISO-certified for the first time (ISO/PAS 16739:2005). The fourth version, IFC4, was published in 2013 and certified as ISO standard ISO 16739 »Industry Foundation Classes (IFC) for data exchange in the construction industry and asset management«. By 2018, IFC4 had been revised in several stages to become IFC4 ADD2 TC1 (published as ISO 16739-1:2018). Notably, the requirements of the software industry from the software certification processes for the MVD Reference View were incorporated into this revision. The most current version is IFC4.3 ADD2 published as ISO 16739-1:2024 in January 2024. All previously published versions of IFC, presented in Fig. 3.11, can be found in the »IFC Specifications Database« from buildingSMART.

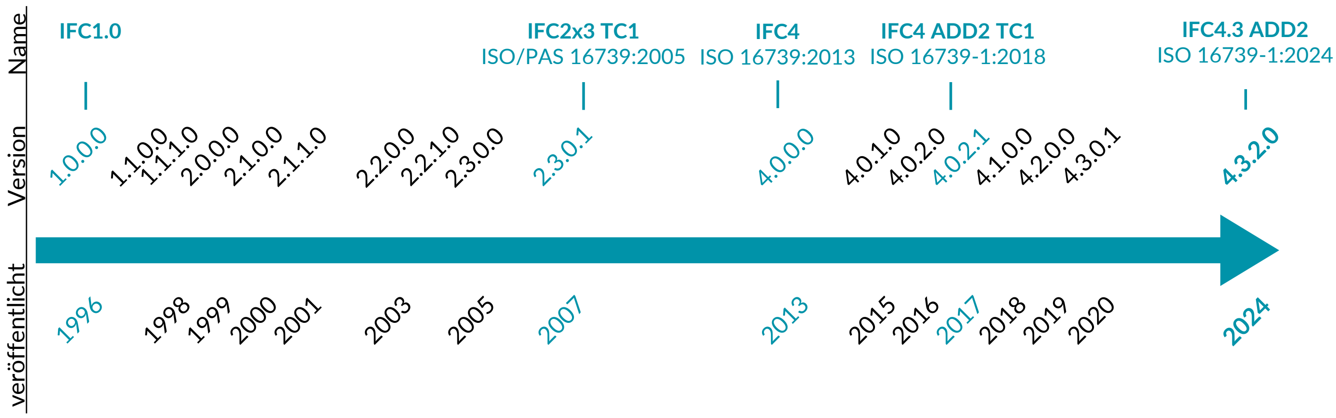
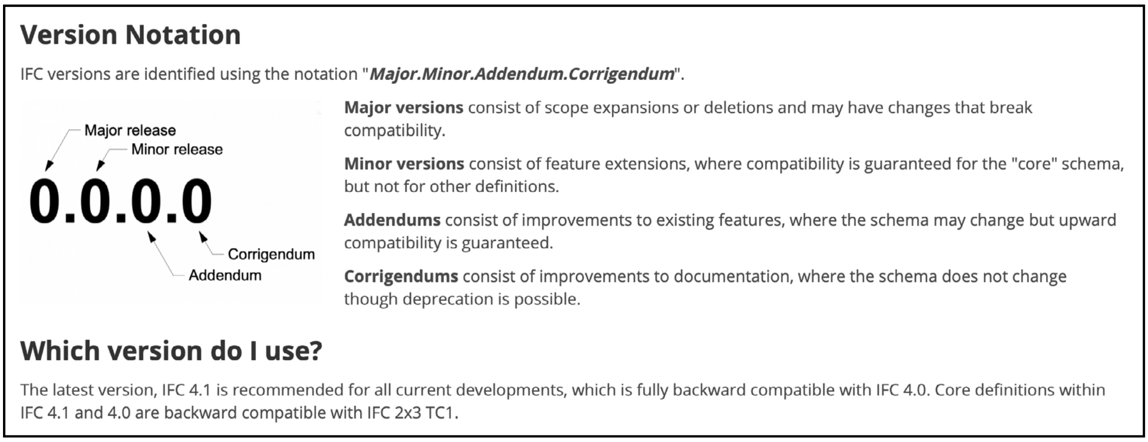


Fig. 3.11: Versions of IFC

Since the development, buildingSMART used various official notations and version designations, e.g. IFC2.0, IFC2x3, and IFC4. At the buildingSMART Summit 2019 in Düsseldorf, buildingSMART presented a new (permanently stable) *version notation* (labelling logic). This has been adopted and can be found on the buildingSMART website (see Fig. 3.12).


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.

Fig. 3.12: IFC version notation

The version notations are made up of four digits, which stand for »*Major.Minor.Addendum.Corrigendum*«. The change of the first digit, signifies significant changes (*major*) that may affect compatibility. A new major version is usually expected every 10 years. This comprises a fundamental leap in development, e.g. a complete revision of the MVD concept with IFC5 (5.0.0.0). With minor changes (*minor*), the compatibility of the »core« schema is guaranteed. Minor versions are therefore intermediate steps for the integration of new functionalities, e.g. the inclusion of IFC alignment within IFC4.1 (4.1.0.0) or the inclusion of data structure components for transport infrastructure facilities (road and rail) within IFC4.3 (4.3.0.1). An *addendum* can contain selective improvements for existing functions, e.g. the introduction of NURBS surfaces for BREP transfer with IFC4 Add2 (4.0.2.0). It is important to note that an upward compatibility is guaranteed. A *corrigendum* does not change the schema per se, but individual functions can be made obsolete (deprecation). Corrigendums are also adjustments/corrections to the documentation, e.g. 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. IFC4.3.rc.1) in a standardised, multi-stage process (Project Delivery Governance, see QR code), which is specified and monitored by the Operations Director of buildingSMART International (see Fig. 3.13).

While the currently most used version in practice is IFC2x3, an increasing replacement by IFC4 is noted due to rising availability of IFC4-certified software. This book refers to the latest IFC specification IFC4.3 (see QR code for documentation).

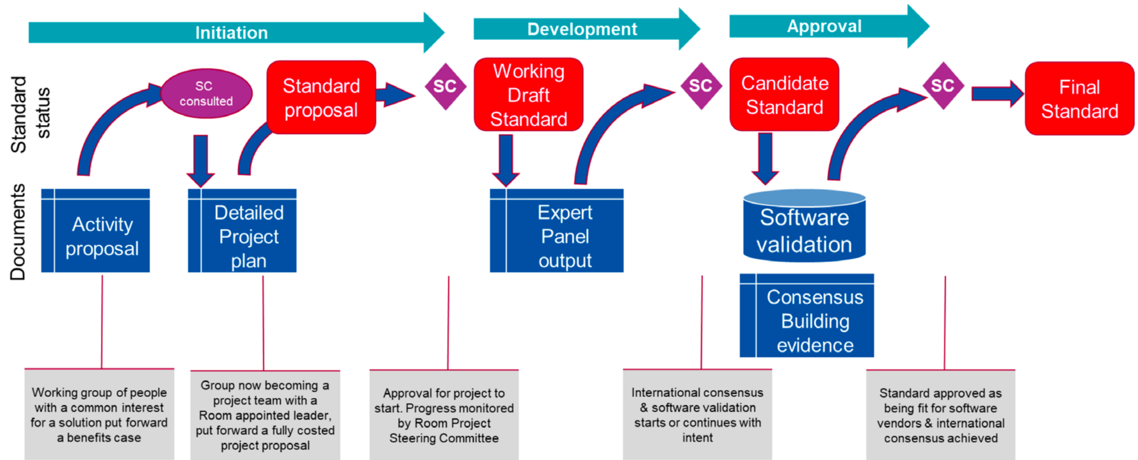


Fig. 3.13: IFC standardisation process

3.2.2.2 Definition of terms

The following definition of terms are based on the IFC4.3 specification (see QR code) as well as definitions and translations from the bSDD.

Entity, also class, element class, EntityType, elements:
According to the IFC definition, an entity is an information class that is defined by common attributes and restrictions, as specified in ISO 10303-11, and acts as a basis for the declaration of model content, representing the basis for the semantics of the model. Standardised attributes and relations to other entities are defined for each entity. In addition, the object-orientated concept of inheritance is implemented, meaning that attributes and relations are passed on from parent entities to child entities. IfcWall, for example, inherits the attributes *GlobalId*, *OwnerHistory*, *Name*, *Description* from IfcRoot, and the attribute *ObjectType* etc. from IfcObject (see Fig. 3.10).

Abstract entity, also abstract classes:
In the IFC data schema abstract entities (e.g. IfcRoot, IfcElement) are used to group entities and pass on common attributes. They do not appear in the actual file (e.g. .ifc, .ifcxml) and are highlighted in grey in the inheritance hierarchy in the IFC data schema documentation or marked with »*Abstract*« in the description.

Object and instance, also exemplar, entity instance, element instance:
An object is a tangible or imaginable object that can exist physically (such as a wall) or be purely conceptual (such as a load, a room, or a task). In the object-oriented modelling used in IFC, an object is also referred to as an instance of an entity. The entity represents a type of template for creating or instantiating objects, therefore describing the structure and behaviour of similar objects.

Attribute:
Attributes are characteristics of an entity. The »*GlobalId*« and the »*name*« are such characteristics. Attributes can therefore be mandatory (*GlobalId*) or optional (*name*). Mandatory attributes are provided or requested by the software, as otherwise no valid data structure can be created.

Quantity:
A quantity is a key figure that is derived from the physical properties of an object, e.g. the floor area of a room or the volume of a component. Possible units of measurement for quantities are, for example, 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 designation is dependent on the associated entity – e.g. Qto_ActuatorBaseQuantities for IfcActuator. Quantity sets that begin with »Qto_« are ISO standardised sets that contain predefined quantities. Individual quantity sets can also be transferred. However, only the ISO standardised quantity sets and quantities should be used when determining quantities – e.g. for tenders.

Property:
A property is a unit of information that is dynamically defined as an entity instance of the IfcProperty entity. It is a characteristic that can be used to actively describe the nature of an object, such as the »*FireRating*« property, which provides information on the fire resistance class of an object.

Property set:
The IfcPropertySet is a container that contains properties in a property tree structure. Some predefined property sets are contained in ISO 16739-1 and in the bSDD. A more detailed explanation of this can be found in Section 3.2.3.6. In addition, any user-defined property set and property can be defined, whereby user-defined property sets must not begin with the prefix »Pset_«.

Naming convention:
The names of the data types are written using the capitalised notation (CamelCase). The first letters of the words are capitalised with no underscore between the individual words. An example of this notation is OwnerHistory. The IFC data schema defines the following naming conventions (see QR code):

- Types, entities, rules, and functions have the prefix »Ifc«.
- Attributes of entities do not have a 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_«.

3.2.2.3 Layer structur

The IFC data schema is very extensive. In addition to the hierarchical structure, four conceptual layers have been introduced to improve maintainability (see previous QR code on the *naming convention*). The description of the layers in this section is important for the maintenance and upkeep of the data schema and is mainly of interest to those directly involved in maintenance.

The four conceptual layers are:

1. Core Layer
This first layer contains the most basic entities of the data model. They can be referenced, i.e. reused and concretised, by entities in the *Interoperability Layer* and the *Domain Layer*. Basic structures, fundamental relations, and general concepts are defined here.
Example: All entities of the three layers presented in Fig. 3.14 have a GUID (*Globally Unique Identifier*).
The *Core Layer* consists of the kernel (core) and the three *Core Extension* sub-schemas (extension schemas), which are used to group basic entities:

- The **kernel** contains the most abstract entity IfcRoot, which is the parent entity of all entities in the first three layers. Direct child entities of IfcRoot are IfcObjectDefinition, IfcPropertyDefinition, and IfcRelationship. IfcObjectDefinition is a parent entity for entities that enable the instantiation and typing of physically tangible or existing objects, persons, and processes. These include, e.g. IfcContext (with the subordinate entities IfcProject and IfcProjectLibrary), IfcElement, IfcSpatialElement (with child entities: IfcSite, IfcBuilding, IfcSpace, etc.), IfcElementType, IfcStructuralActivity, IfcStructuralItem, IfcActor, IfcProcess, and IfcResource. IfcPropertyDefinition contains entities for grouping properties and for providing templates for properties. Examples of associated entities are IfcPropertySet, IfcQuantitySet, IfcPropertyTemplateDefinition, and IfcPreDefined-

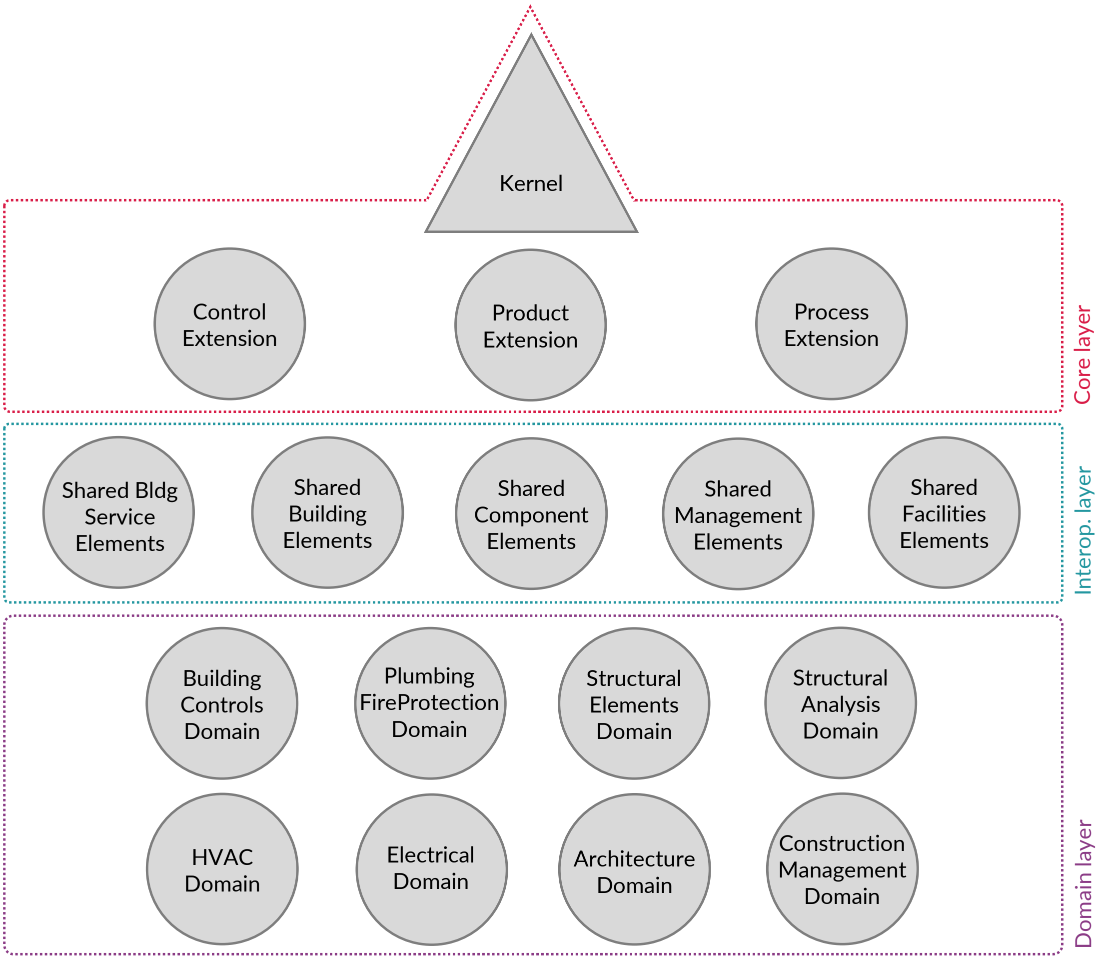


Fig. 3.14: Illustration of the layer structure

PropertySet. The concept of properties is described in detail in Section 3.2.3. IfcRelationship is the superordinate entity for all relationship objects that are used to link entities. It describes relationships between objects, properties, as well as objects and properties.
- The **control extension** declares basic entities for control objects (IfcControl and IfcPerformanceHistory, etc.) and relationship entities for assigning these control objects to other objects (such as IfcRelAssignsToControl). IfcControl contains entities that control or restrict the use of products, processes, and resources through rules, requests, or instructions.
- The **product extension** specialises in entities of physical objects that usually have a shape and a location within the project. These are, for example, elements for creating a spatial project structure and construction elements. The product information is provided for objects as child entities of IfcProduct and for object types as child entities of IfcTypeProject.
- The **process extension** extends the concept of the IfcProcess described in the kernel. It contains entities for the logical mapping of processes and for task and work planning. The aim is to map information that is frequently used in process mapping and scheduling applications. Examples of entities in the schema are IfcTask, IfcWorkPlan, and IfcEvent. IfcTask is used for identifiable work units, e.g. as part of the design or construction process. An IfcWorkPlan is a work plan that can reference other work plans of the entity IfcWorkSchedule, tasks of the entity IfcTask, 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 released.

2. Interoperability Layer:
This *layer* contains entities that can be used in different disciplines and exchanged between them. They can be referenced and specialised by all entities that are located below them in the hierarchy – i.e. in the *Domain Layer*.
- The most important component of this layer is the *Shared Building Elements* schema, which contains important component entities such as IfcWall and IfcSlab. These and other child entities of IfcElement are used to represent the most important functional parts of a building. The entities of the *Interoperability Layer* are derived from entities of the *Core Layer*, as in the case of the entities of the *Shared Building Elements* schema from IfcElement.
- The *Shared Building Service Elements* schema defines entities for modelling flow and distribution systems and feature lists for describing building services, such as flow properties, electrical properties, and room thermal properties.
- The *Shared Component Elements* schema contains concepts for various small parts such as accessories and fastening elements. One entity worth mentioning is IfcElementComponent, which provides a representation for smaller elements that are not relevant when regarding the overall building structure, e.g. fasteners.
- *Shared Management Elements* defines concepts for the management of the project. The entities of the schema are subordinate entities of IfcControl. The aim is to provide information entities that support the control of the project scope, costs, and time.
- *Shared Facilities Elements* defines basic entities for facility management (FM), including entities for mapping furniture and other items.

3. Domain Layer
This layer organises element entities according to construction disciplines. The elements are used to represent buildings and are organised in *domains* (*domain-specific data schemas*) such as the IfcArchitectureDomain or the IfcHVACDomain (corresponding to the typical division of design disciplines). The layer 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. The entities in this level cannot be referenced or further specialised by any other level. This declaration enables a clear assignment of responsibilities or filtering of model content during import or export. In addition, the *shared element data schemas* provide a parallel-managed restriction of element entities that are used by several domains in parallel. One example of this is the IfcSharedBldgElements, such as walls, ceilings, columns, and beams. These are used by both architecture and structural engineering in equal measure.

4. Resource Layer
This separate layer (see Fig. 3.15) contains all schemas that contain supporting resource definitions. As these entities are not child entities of IfcRoot (which is why they are also called non-rooted entities), they have no GUID and cannot exist as independent elements. They must be referenced by at least one entity of one of the other three layers. Examples of these entities are IfcMaterial, IfcCartesianPoint, IfcFacetedBrep, IfcPerson, IfcPropertySingleValue, IfcObjective or IfcRegularTimeSeries. Essential entities of the layer are, e.g. MaterialResource, GeometricModelResource, and PropertyResource.

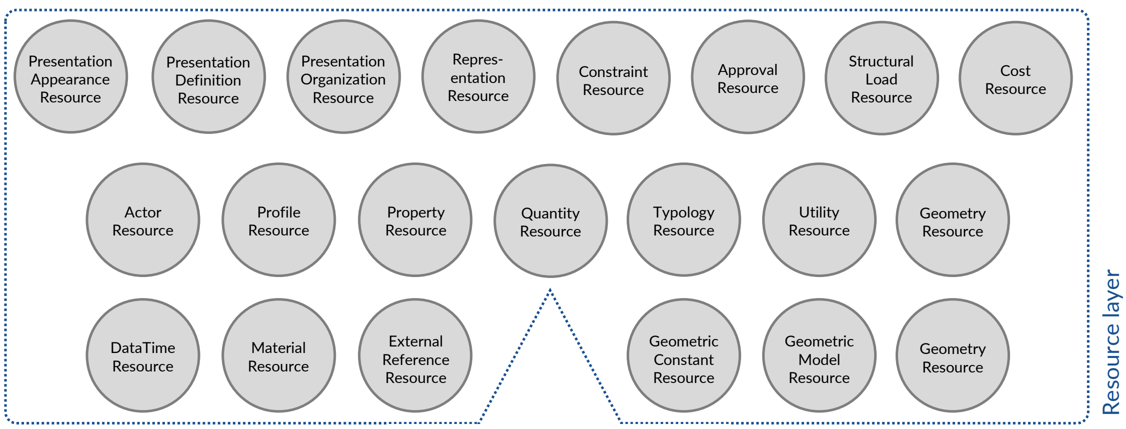


Fig. 3.15: Resource Layer

The conceptual layers of the data schema architecture are shown in Fig. 3.16 based on a use case. The entity IfcWall (see QR code) is part of the *shared building elements schema*, which is in the *Interoperability Layer*. It is a child entity of IfcBuiltElement of the *Product Extension* schema in the *Core Layer*. The inheritance structure continues upwards via the parent entities IfcElement and IfcProduct (both also in the *product extension schema*) and the entities IfcObject and IfcObjectDefinition in the kernel, right up to the most abstract of all entities: IfcRoot. IfcRoot is the origin of all entities in the *Core Layer*, *Interoperability Layer*, and *Domain Layer*.

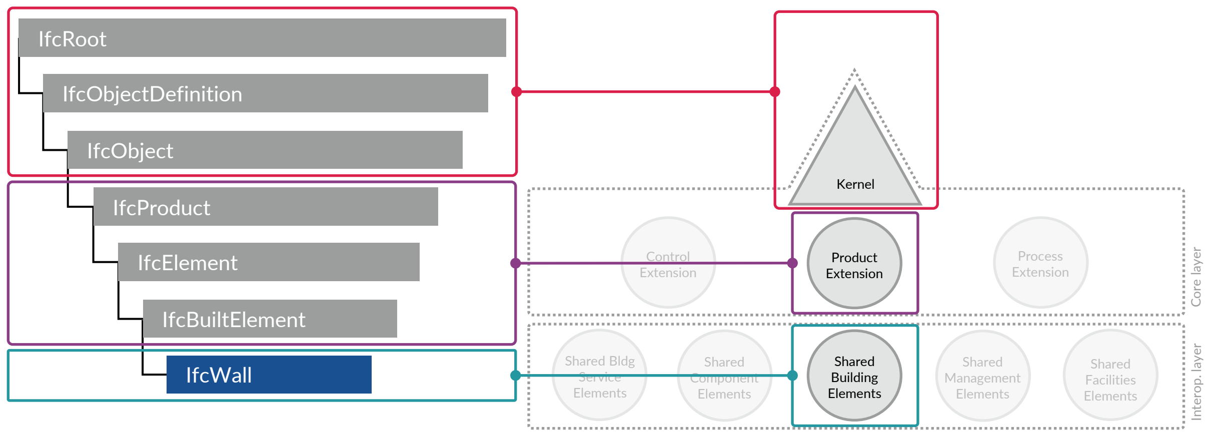


Fig. 3.16: Linking layer structure with inheritance hierarchy

3.2.2.4 Inheritance hierarchy

The data schema is structured according to inheritance logic. IfcRoot is the top-level entity (except for entities from the *Resource Layer*). Based on this entity, relationships and attributes are inherited in IFC. In programming, inheritance means that a subordinate (child) entity can inherit the properties of one or more higher-level (parent) entities. The child entities therefore have additional information and represent specialisations. The inheritance of attributes is explained below using the IfcWall entity. Fig. 3.17 shows the inheritance hierarchy of IfcWall with the parent entity being IfcBuiltElement.

Up to and including IFC4, the name of the parent entity of IfcWall was IfcBuildingElement. In addition to IfcBuildingElement (building construction), IfcCivilElement (civil engineering) (marked red in Fig. 3.17) also existed. However, many elements from building construction are also used in civil engineering, which is why building construction and civil engineering were combined in IfcBuiltElement, with IfcCivilElement removed from IFC4.3 onwards.

Exemplary entities that are on the same hierarchy as IfcWall are IfcBeam and IfcSlab. IfcWall receives its available attributes from the entities IfcRoot, IfcObjectDefinition, IfcObject, IfcProduct, IfcElement, IfcBuiltElement, and from IfcWall itself.

Fig. 3.18 lists the attributes for IfcWall, organised according to their origin (see QR code for IfcWall). It shows which characteristics are inherited by attributes from parent entities. The figure shows the attributes of IfcRoot that are inherited by all entities that have their origin in the kernel, i.e. all except those of the *Resource Layer*. IfcRoot thus forms the root of the inheritance tree of most entities in the IFC data schema. It provides the attribute *GlobalId* (IfcGloballyUniqueId – GUID), which is required to uniquely identify the objects. The GUID is generated automatically and is a 128-bit number that is compressed to a 22-digit number to reduce the storage space required for data exchange. *OwnerHistory* is another attribute of IfcRoot and provides information on the current and past ownership and the time of the last change to the object. The *Name* and *Description* attributes offer the option of adding a name or a comment. The only attribute of IfcWall that is not inherited from a parent entity is the *PredefinedType* (see Section 3.2.3.2).

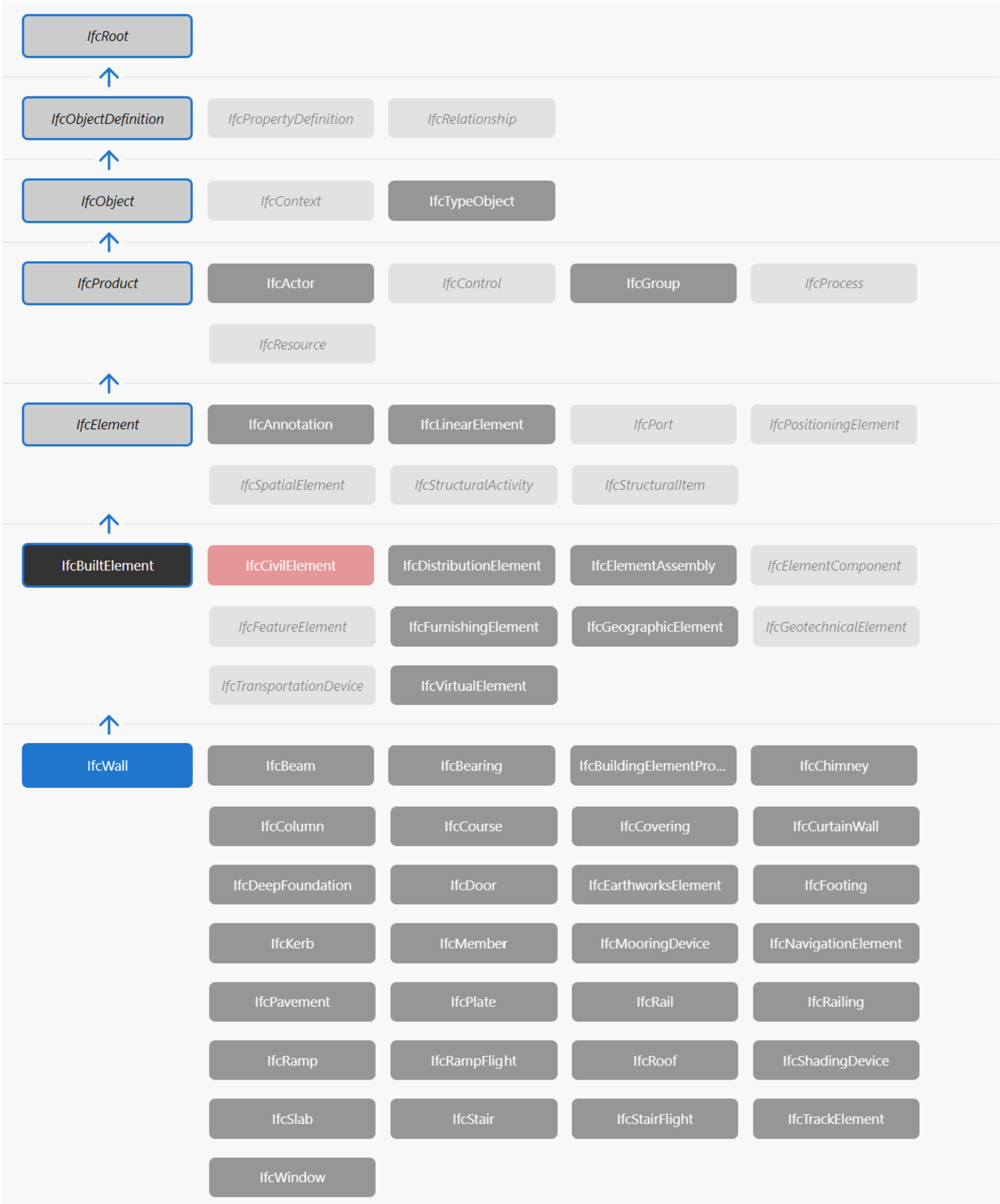


Fig. 3.17: Represenation of inheritance of the entity IfcWall in the IFC data shema

3.2.3 Contents of an IFC file

This section deepens the understanding of the IFC data schema by taking a detailed look at the contents of an IFC file, supported by examples in the STEP file format. To reduce complexity and facilitate understanding, the description focuses on selected aspects of the IFC data schema rather than its entirety. To ensure a clear and comprehensible description, the content of the IFC file is divided into the following five categories:

Attribute aus IfcRoot

#	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,
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.
4	Description	OPTIONAL IfcText	Optional description, provided for exchanging informative comments.
IfcObject (5)			
5	ObjectType	OPTIONAL IfcLabel	The type denotes a particular type that indicates the object further. The use has to be established at the level of instantiable subtypes. In particular it holds the user defined type, if the enumeration of the attribute *PredefinedType* is set to USERDEFINED or when the concrete entity instantiated does not have a PredefinedType attribute. The latter is the case in some exceptional leaf classes and when instantiating IfcBuiltElement directly.
IfcProduct (5)			
6	ObjectPlacement	OPTIONAL IfcObjectPlacement	This establishes the object coordinate system and placement of the product in space. The placement can either be absolute (relative to the world coordinate system), relative (relative to the object placement of another product), or constrained (e.g. relative to grid axes, or to a linear positioning element). The type of placement is determined by the various subtypes of *IfcObjectPlacement*. An object placement must be provided if a representation is present.
7	Representation	OPTIONAL IfcProductRepresentation	Reference to the representations of the product, being either a representation (*IfcProductRepresentation*) or as a special case of a shape representation (*IfcProductDefinitionShape*). The product definition shape provides for multiple geometric representations of the shape property of the object within the same object coordinate system, defined by the object placement.
IfcElement (13)			
8	Tag	OPTIONAL IfcIdentifier	The tag (or label) identifier at the particular instance of a product, e.g. the serial number, or the position number. It is the identifier at the occurrence level.
IfcWall (1)			
9	PredefinedType	OPTIONAL IfcWallTypeEnum	Predefined generic type for a wall that is specified in an enumeration. There may be a property set given specifically for the predefined types.

Fig. 3.18: Inheritance of attributes using the example of IfcWall

1. General content (header, organisation, units),
2. spatial level,
3. element level,
4. ressources,
   a. *material*,
   b. *property*,
   c. *classification* (see Section 3.8 on bSDD), and
5. *relations*.

This systematic approach is intended to promote a sound understanding of the IFC data schema and demonstrate its application in practice, particularly when using the STEP file format. Fig. 3.19 puts all categories into context with each other. Each IFC file has the entity IfcProject. The *spatial level* (property, floor, rooms with functions) is based on this in the model. The *elements* (e.g. wall, ceilings) are then incorporated into the *spatial levels* and documented in the data schema in various groups (e.g. IfcBuiltElement, IfcDistributionElement). *Relations* are used to link the *elements* and the *spatial level*. An *element* also has *relations* with *classification*, *property set / property*, and *material* (IfcMaterial). The *material* itself can in turn have its own relations to *classifications* and *properties*. Unfortunately, *material* assignment is implemented very heterogeneously in the BIM software applications currently available on the market. This is set to change in the medium term with ISO 23386. This standard for *DataSheets* regulates the interaction between building information and material or product information. IFC5 may therefore also lead to a change in the material data structure.

Renaming levels:
Until the second edition of the *BIMcert Handbook*, the *levels* were called *spatial structure*, *functional structure*, and *material structure*. To create a stronger link to the *data schema* (*layer*) and to represent a greater functional scope of IFC, these *levels* have now been renamed.

Material:
The consistent separation of properties for material and elements is essential for a standardised structure but is not yet fully implemented. An example of this is the entity IfcWall, for which information about the material properties can be entered via the property set Pset_ConcreteElementGeneral. However, this should be reserved for the IfcMaterial entities. The consistent separation is intended to ensure that materials do not appear multiple times in the structure but are merely referenced multiple times.

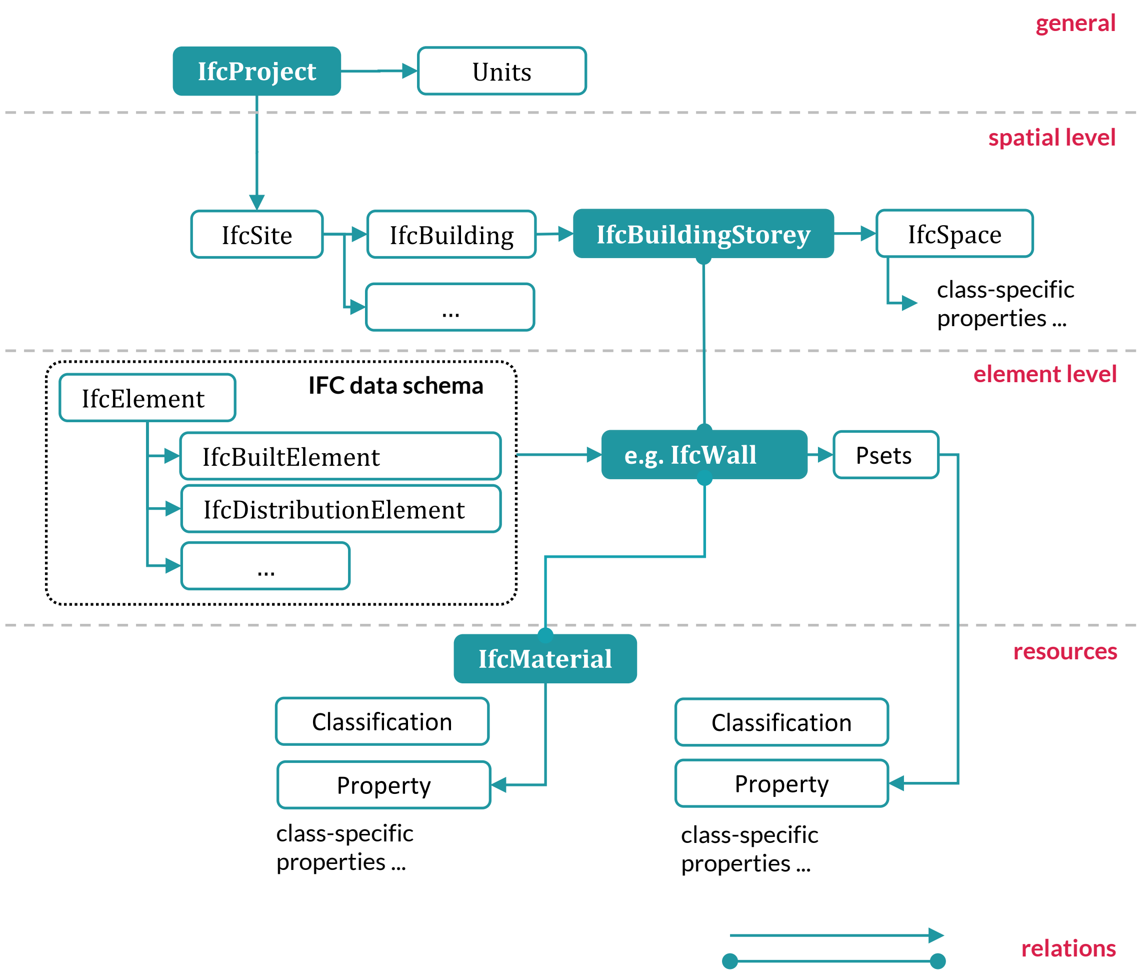


Fig. 3.19: Structure of an IFC file

3.2.3.1 General conents

An IFC file can be opened with any text editor. Each IFC file consists of a HEADER section and a DATA section. The HEADER section contains information on the model view definition, the file name and path, the author, the software used, and the IFC data schema that was used for the export. A HEADER section can look like this:

```
ISO-10303-21;
HEADER;FILE_DESCRIPTION(('no view'),'2;1'); FILE_NAME('C://der/
pfad/zur/datei.ifc',('Linda'),('Software Name', 'Konrad-Zu 1,
Germany'), 'EDMsix Version 2.0100.09 Sep 7 2016',
'Allplan 2019.1 24.06.2019 16:10:06',''); FILE_SCHEMA(('IFC4'));
ENDSEC;
```

The DATA section, as presented in Fig. 3.20, contains all the information about the project. In STEP Physical File Format, each instance is given a file-internal identifier (*ExpressID*), which consists of a number preceded by a # character. These are used for referencing between the entities. In Fig. 3.20, for example, IfcWall references the IfcOwnerHistory. The first section contains information on the *creator*, *organisation*, and IfcOwnerHistory. Subsequently, the units are defined.

Ersteller

Einheiten

```
DATA;
#1= IFCPERSON($,'Nicht definiert',$,$,$,$,$,$);
#3= IFCORGANIZATION($,'Nicht definiert',$,$,$);
#7= IFCPERSONANDORGANIZATION(#1,#3,$);
#10= IFCORGANIZATION(,GX‘,‘X‘,‘X',$,$);
#11= IFCAPPLICATION(#10,‘XXX‘,‘XXX','IFC add-on version: 3001 AUT FULL');
#12= IFCOWNERHISTORY(#7,#11,$,.NOCHANGE.,$,$,$,1704713129);
#13= IFCSIUNIT(*,.LENGTHUNIT.,$,.METRE.);
#14= IFCSIUNIT(*,.AREAUNIT.,$,.SQUARE_METRE.);
#15= IFCSIUNIT(*,.VOLUMEUNIT.,$,.CUBIC_METRE.);
...
#256= IFCWALL('2C45vBrGbB_w_CB97snkya',#12,'WandBeispiel-001‘,
$,$,#178,#244,'8C105E4B-D509-4BFB-AF8C-2C91F6C6EF24',.NOTDEFINED.);
...
```

Referenzierung mit dem Identifikator #12 auf die Klasse IfcOwnerHistory

Fig. 3.20: Begin of a DATA section

3.2.3.2 Element level – IfcElement and its child entities

The basic component for the element level is the abstract entity IfcElement. IfcElement is a generalisation of all physically existing components that make up a building. It is a parent entity for several particularly important elements that are required to describe buildings. Fig. 3.21 shows all child entities of IfcElement on the left. The IfcElement child entity IfcBuiltElement is particularly relevant for buildings. Its child entities are elements such as IfcWall, IfcSlab, IfcColumn, and IfcWindow. With IFC4.3, IfcBuiltElement also contains horizontally organised elements that occur in linear infrastructure systems for road, bridge, and rail construction (e.g. IfcCourse, IfcRail).

Another child entity of IfcElement is IfcDistributionElement, which contains elements for supply systems that are used in the MEP sector. These can be used for heating and cooling systems, wastewater systems and electrical systems, among others.

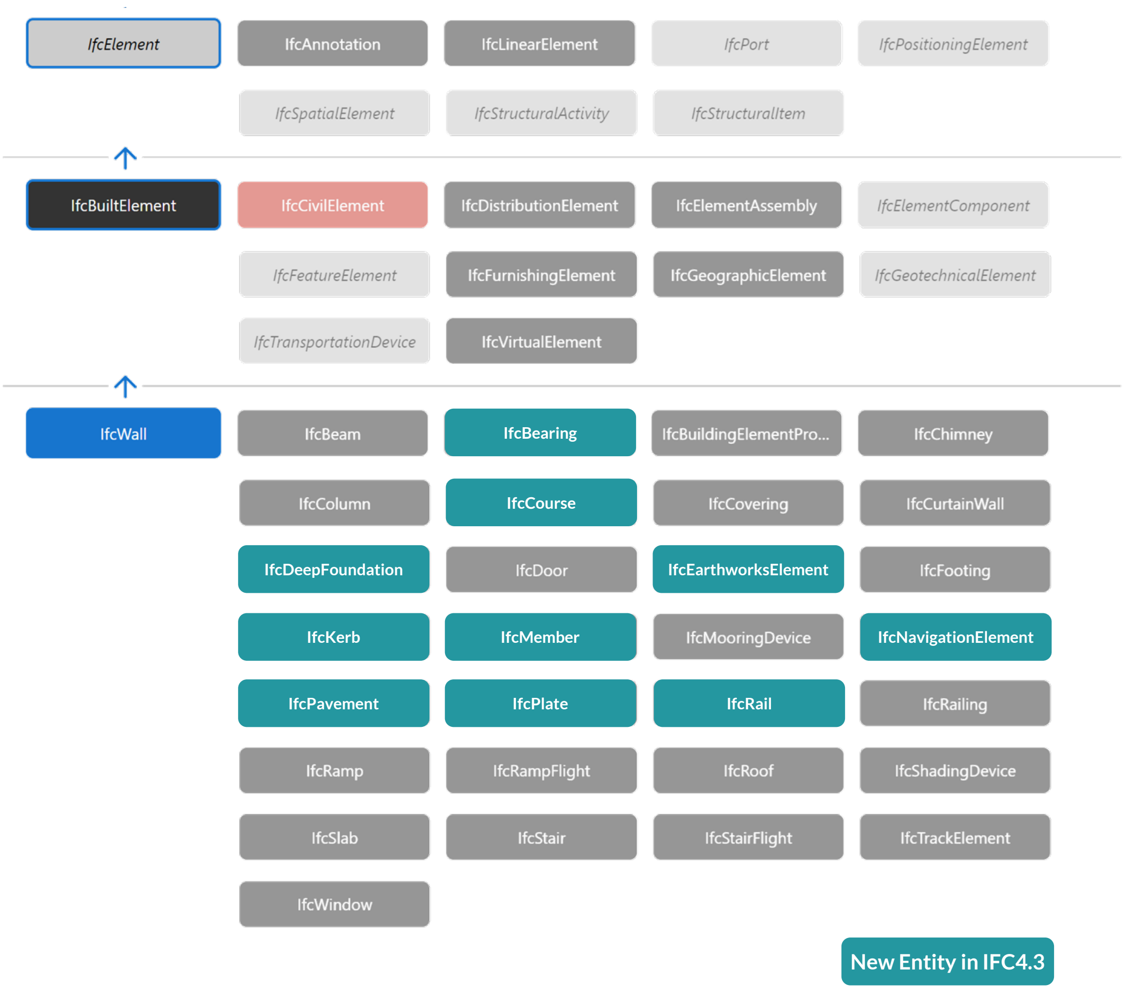


Fig. 3.21: Illustration of the different child entities of IfcElement

The child entities of IfcElement have a clear definition of their area of application. This is accompanied by a limitation of their geometric functionality (position, path, dimension), the quantity sets that can be derived from them and the properties that are fundamentally necessary for the description (organised in Psets). For example, an IfcWall has the property set Pset_WallCommon and the associated properties. In addition, the *material layer set* for each entity provides a concrete specification for the assignability of materials. This can be a layered definition for IfcWall or a differentiation between front, filling, and back for IfcCovering. The material declaration enables a free definition of materials for which freely defined properties can be transported. Although the IFC specification offers detailed predefined material properties, these have not yet been implemented in every BIM software application. In general, the introduction of *DataTemplates* (in accordance with ISO 23386/23387) is expected to lead to a change in the way building data (IFC) and product information (*DataTemplates*) are managed.

The IfcBuildingElementProxy entity provides an element for any application areas for which the IFC specification used does not yet have semantics – i.e. a suitable child entity of IfcElement. In rare cases, if a specified entity is not implemented in an application, IfcBuildingElementProxy can be used. However, in such cases, care must be taken to ensure that this deviation is communicated within the project team (usually in the *BIM execution plan BEP*). The new ISO 16739-1:2024 for IFC4.3 recommends the use of IfcBuiltElement instead of IfcBuildingElementProxy if enabled by the software. IfcBuildingElementProxy is currently still frequently used in transport infrastructure projects that are processed with IFC2x3, as the currently implemented BIM software applications only offer stable support for this entity.

PredefinedType

The entities can be declared more precisely by specifying a type. This is made possible by the »*PredefinedType*« field (see Fig. 3.22, position 9). This is additional information that can be used to narrow down the necessary properties. The type of entity (e.g. IfcWall) remains unaffected. Many child entities of IfcElement already have predefined types in the IFC data schema called *PredefinedType* declarations. IfcWall, for example, has predefined types such as »MOVEABLE«, »SOLIDWALL«, »NOTDEFINED«. Fig. 3.22 shows three walls (IfcWall) with different *PredefinedType* declarations in a STEP file. Each child entity of IfcElement can be assigned the *PredefinedType* USERDEFINED, whereby any type can be defined under the *ObjectType* attribute (e.g. attica). In *exchange information requirements (EIR)* properties can therefore be assigned not only at entity level (e.g. IfcWall), but also at *PredefinedType* level (e.g. IfcWall.Userdefined.Attika). In addition, any used USERDEFINED declarations must also be standardised for the project team in the EIR or BEP.

```
#256= IFCWALL('2C45vBrGbB_w_CB97snkya',#12,'WandBeispiel-001'
,$,$,#178,#244,'8C105E4B-D509-4BFB-AF8C-2C91F6C6EF24',.NOTDEFINED.);

#256= IFCWALL('2C45vBrGbB_w_CB97snkya',#12,'WandBeispiel-001'
,$,$,#178,#244,'8C105E4B-D509-4BFB-AF8C-2C91F6C6EF24',.MOVEABLE.);

#256= IFCWALL('2C45vBrGbB_w_CB97snkya',#12,'WandBeispiel-001'
,$,'ATTIKA',#178,#244,'8C105E4B-D509-4BFB-AF8C-2C91F6C6EF24',.USERDEFINED.);
```

PredefinedTyp

Fig. 3.22: Representation of differen IfcWall types in STEP file format

IfcBuildingElementPart

There are specific entities for various elements in the IFC structure. Wall elements, for example, can be represented by IfcWall and ceilings are represented by IfcSlab, with the elements defined geometrically on their own. However, the individual elements can also consist of different layers or parts (IfcBuildingElementPart) with their own geometry, allowing for a representation of geometrically complex structures, e.g. the layers of a wall can each be defined as IfcBuildingElementPart and the entire wall structure as IfcWall.

Since IFC4 IfcBuildingElementPart can also contain property sets and properties. In most EIR, however, the information requirements are defined at component or entity level (e.g. IfcWall). Layer-by-layer information can also be transmitted via the material (see Section 3.2.3.5), which is assigned to the respective IfcBuildingElementPart.

IfcElementType

An element, e.g. wall, is geometrically and alphanumerically represented completely via IfcWall. In many projects, however, there are numerous identical components (IfcWall, IfcSignal ...) that share the same information. IfcElementType was introduced to describe frequently recurring components efficiently – in terms of file size. A reusable pattern (types) is predefined for this purpose, i.e. a »template«. Corresponding object types are available for most IfcElement child entities, which have the same name as the entity with

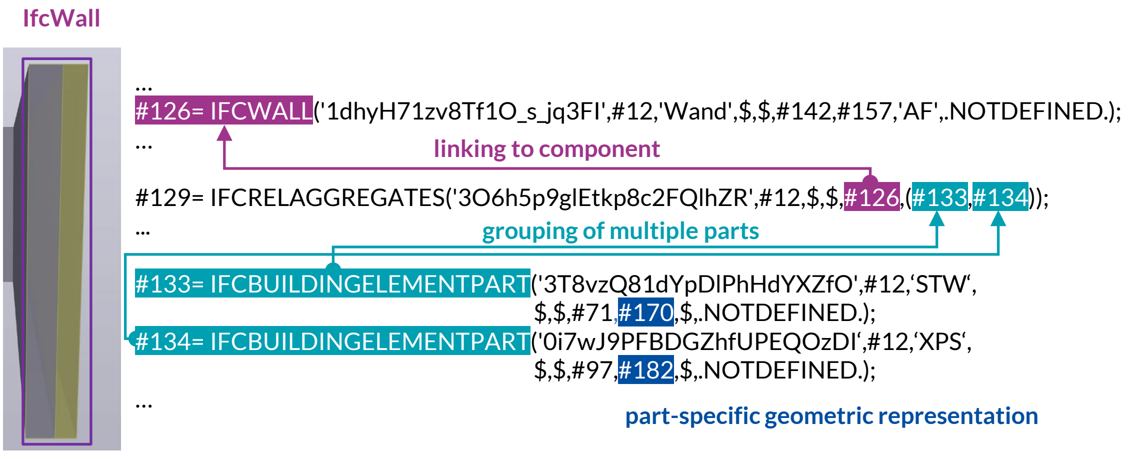


Fig. 3.23: Structure of an IfcWall with IfcBuildingElementPart in a STEP file format

the additional suffix »*Type*«, e.g. IfcDoorType for the element IfcDoor. These types define shared information and assign it to several elements. The set of shared information can include the following:

- common properties within common property sets,
- common material information,
- common definitions of material layers,
- common geometric representation, etc.

A possible application is the definition of common property sets (see Fig. 3.24) and material information in a file, assigning it to several walls.

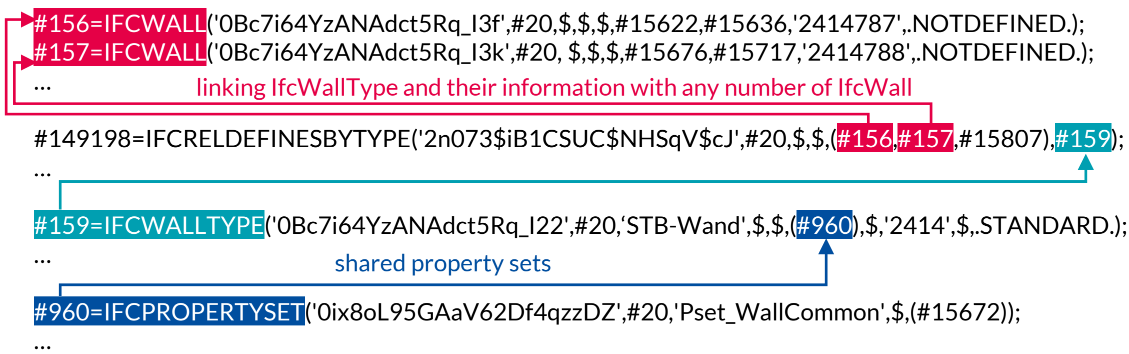


Fig. 3.24: Relation between IfcWall, IfcMaterial, Properties in a STEP file

Another possible application is the exact geometric and alphanumeric definition of IfcSignalType or IfcWindowType that is then assigned to any number of instances of IfcSignal or IfcWindow. The localisation information is the only information remaining for these individual IfcSignal or IfcWindow instances (component-related origin – see Section 3.2.3.4).

3.2.3.3 Relations

Using the concept of object relations, entities (e.g. IfcWall) can be linked to other entities (e.g. IfcSpace). In IFC, this is done using the principle of objectified relations. This means that the association between two objects is established via a separate, intermediate entity that represents the relations. These relation entities are always a child entity of the Ifc-

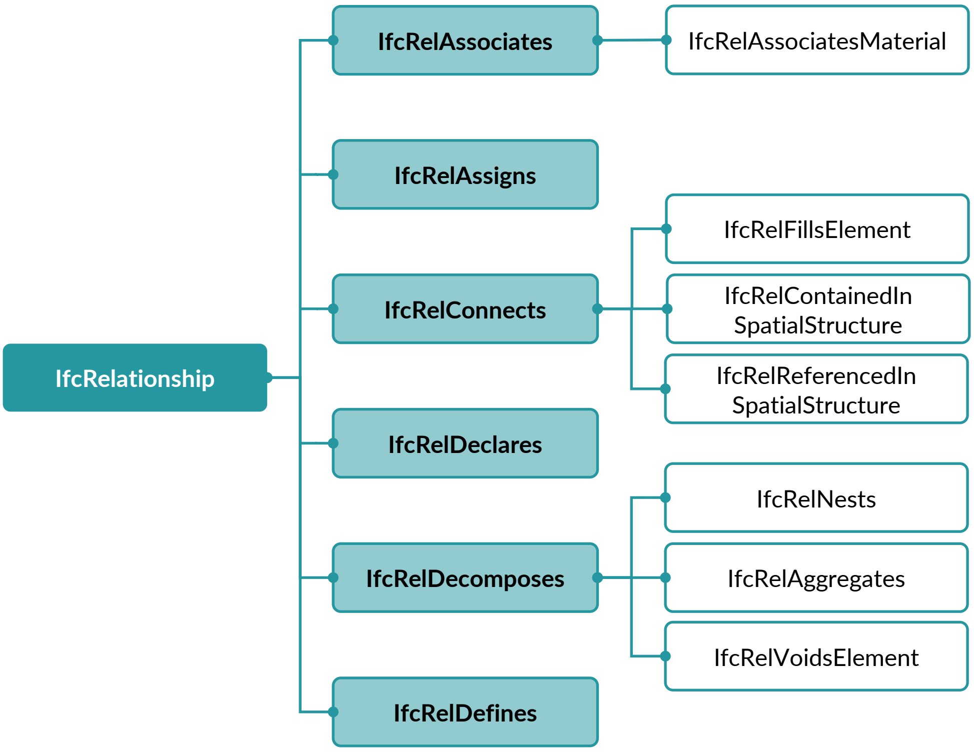


Fig. 3.25: IfcRelationship and its child entities in the IFC data schema

Relation entity. The relation objects are linked to the objects via attributes that begin with *Related* or *Relating*. The five direct child entities of IfcRelation and some of their child entities are shown in Fig. 3.25.

IfcRelAssociates links information sources for materials, documents, and restrictions that are located inside or outside the project data with objects of the entities IfcObject, IfcTypeObject or, in certain cases, IfcPropertyDefinition. Details on IfcRelAssociatesMaterial can be found in Section 3.2.3.5.

IfcRelDecomposes is translated in IFC as »part-to-whole relation«. It defines the general concept of composite or decomposed elements. With this relation entity, a part-to-whole hierarchy can be formulated, with the possibility to navigate from the whole (the composition) to a part and vice versa. There are several types of decompositions: the entity IfcRelNests, which is used, for example, to link cost elements in a so-called *nest* with others, or the entity IfcRelAggregates, which can, for example, represent a frame construction as a grouping (*aggregation*) of a beam and a column. This entity is also used to link spatial objects (see Section 3.2.3.4). Furthermore, the entity IfcRelVoidsElement offers the option of modelling an opening into an element. An instance of this entity for modelling an opening in a wall can be found in Fig. 3.26.

IfcRelDefines contains child entities for the assignment of IfcElementType (IfcWallType) to IfcElement (IfcWall) (see Fig. 3.24), for the assignment of Psets to entities (see Fig. 3.39) and for the assignment of *property set templates* to Psets.

IfcRelConnects contains entities that create connections between objects under special conditions. In the example of the child entity IfcRelContainedInSpatialStructure (see

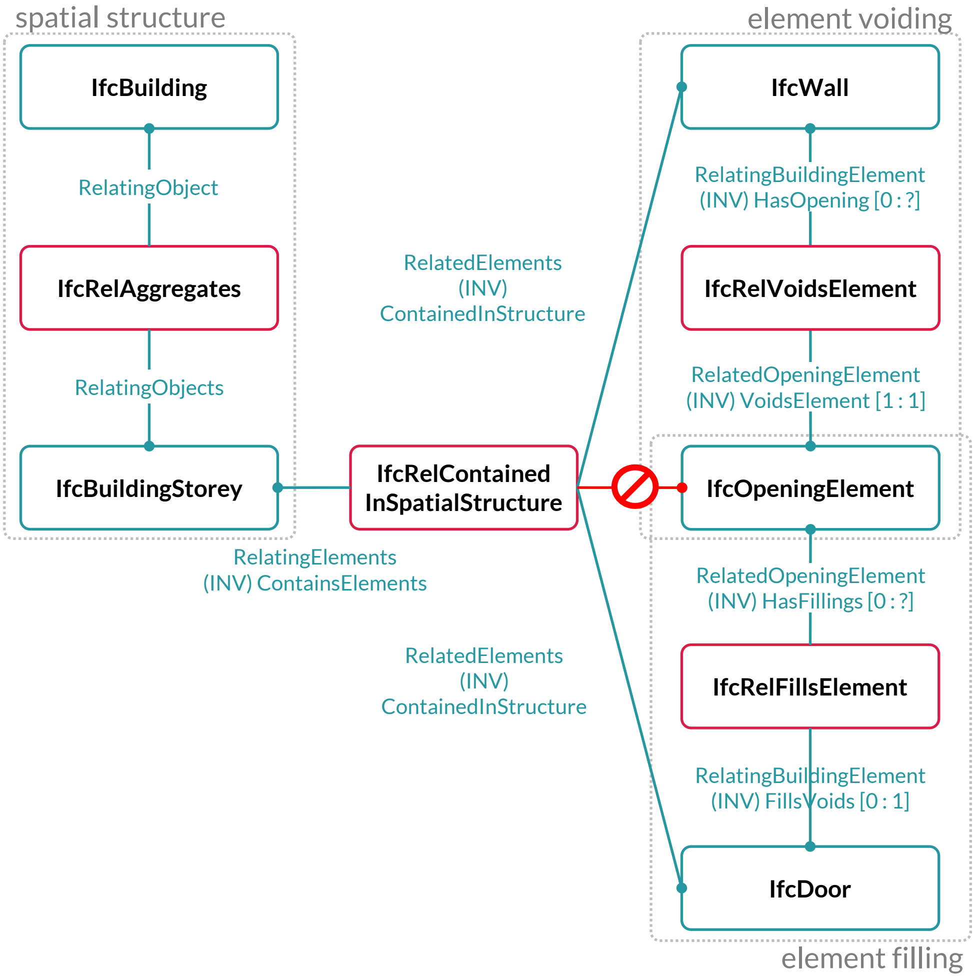


Fig. 3.26: Relation between wall, door, opening, and storey (IfcRelFillsElement)

Fig. 3.30), this involves the condition that an object can only be assigned to a single spatial structure element. IfcRelReferencedInSpatialStructure is used to assign an object to an additional spatial structure element (e.g. for facade elements spanning over several storeys). The entity IfcRelFillsElement enables a one-to-one relation between an opening and an element that fills it, such as a door in a wall opening. This example is illustrated in Fig. 3.26. The opening itself is only linked to the elements, i.e. in the presented example to the door and the wall, and not to the room object where it is located.

IfcRelAssigns is the parent entity for various »*link*« relations that can be used between instances of IfcObject and their direct child entities. A »*link*« refers to the assignment in which the object *Client* uses the services of the object *Supplier*. An example thereof is shown in Fig. 3.27, where an instance of the IfcResource child entity IfcLaborResource is assigned as a supplier to an instance of the IfcProcess child entity IfcTask (as a client). The relation object for this link is the IfcRelAssigns child entity IfcRelAssignsToProcess.

Fig. 3.27: Example for IfcRelAssigns

Relations establish simple connections between the entities, but they do not contain any geometric information. Geometric information is attached to the individual entities (IfcProductRepresentation).

3.2.3.4 Spatial level – spatial structure

The spatial structuring of the components is also fundamental for every building model. When creating a project, the *first step* is to create the so-called *spatial structure*. The components are then logically embedded within. The spatial structure options have been significantly expanded in IFC4.1. While it was only possible to describe building structures for structural engineering – and this was also used improvisationally for infrastructure projects – up to IFC4, buildingSMART published a complete infrastructure supplement with IFC4.1. IFC4.3 subsequently added the corresponding declarations for road and rail at element level and has been an ISO standard since January 2024.

In IFC, the spatial structure consists of child entities of **IfcSpatialStructureElement**. Fig. 3.28 shows IfcSpatialStructureElement and its child entities in the new IFC4.3 data schema. IfcFacility has been added, which now contains the spatial elements IfcBuilding (already existing), IfcBridge, IfcMarineFacility, IfcRailway, and IfcRoad. In addition, a further subdivision of the new elements was made possible by IfcFacilityPart.

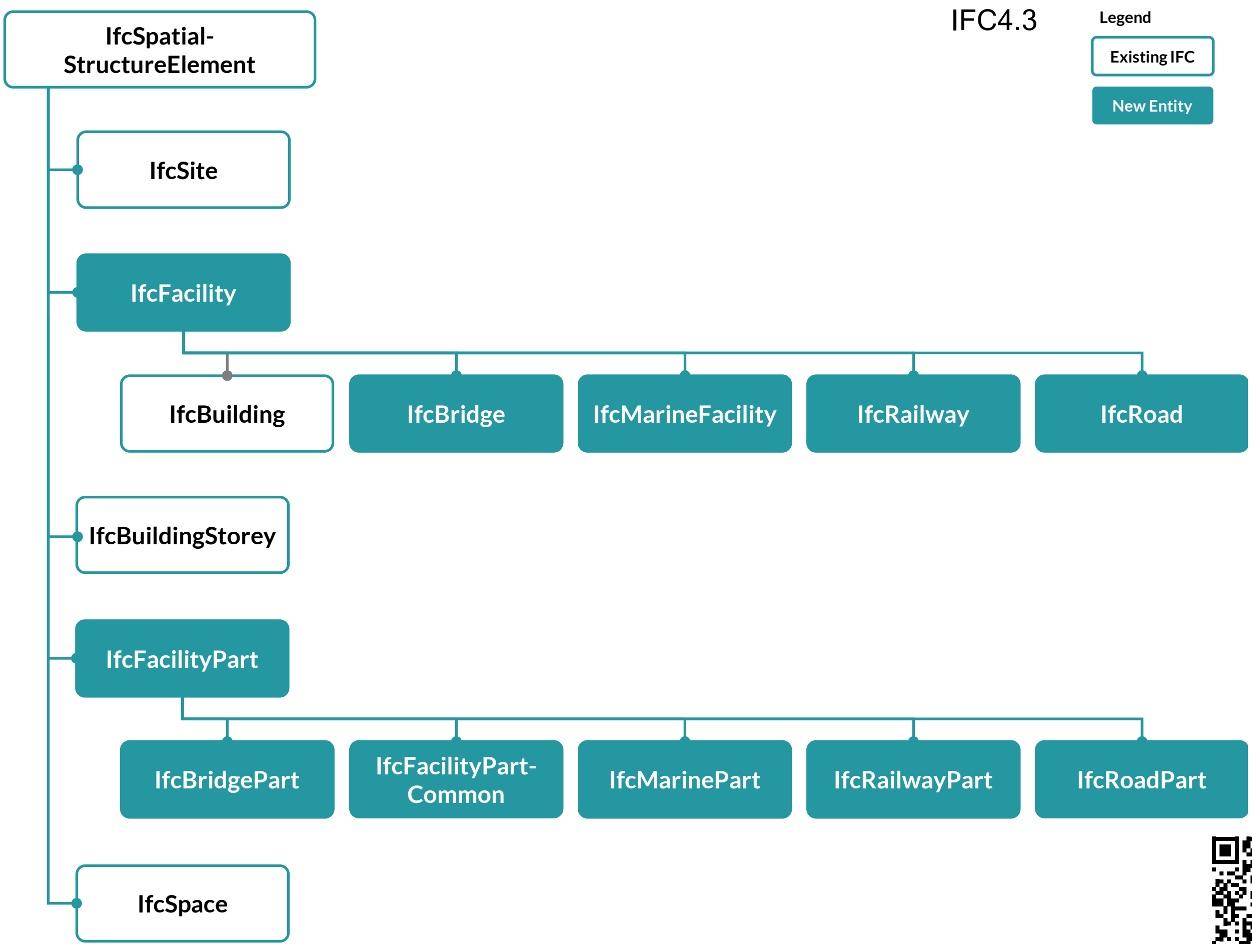


Fig. 3.28: Data schema IFC4.3 IfcSpatialStructureElement

For building constructions, the entities IfcSite, IfcBuilding, and IfcBuildingStorey form the spatial structure (i.e. construction site, building, and storey). In the case of linear structures, for example, the spatial structure includes IfcSite, IfcRoad, and IfcRoadPart. The spatial elements are linked to a hierarchical project structure via relation objects of the IfcRelAggregates entity; this is described below as a spatial relation. However, geometric location information is not passed on via the spatial relation, but rather using IfcLocalPlacement or IfcLocalLinearPlacement (linear structures), described as spatial placement.

Spatial relation – building construction

The spatial relations in building construction remain unchanged within IFC4.3. Fig. 3.29 shows the linking of the IfcSpatialStructure elements using IfcRelAggregates for building construction. The spatial relation takes place in the following order: site, building, and (finally) storey. The relation entities IfcRelContainedInSpatialStructure are used to assign components to the IfcSpatialStructure elements. It is worth noting that each component

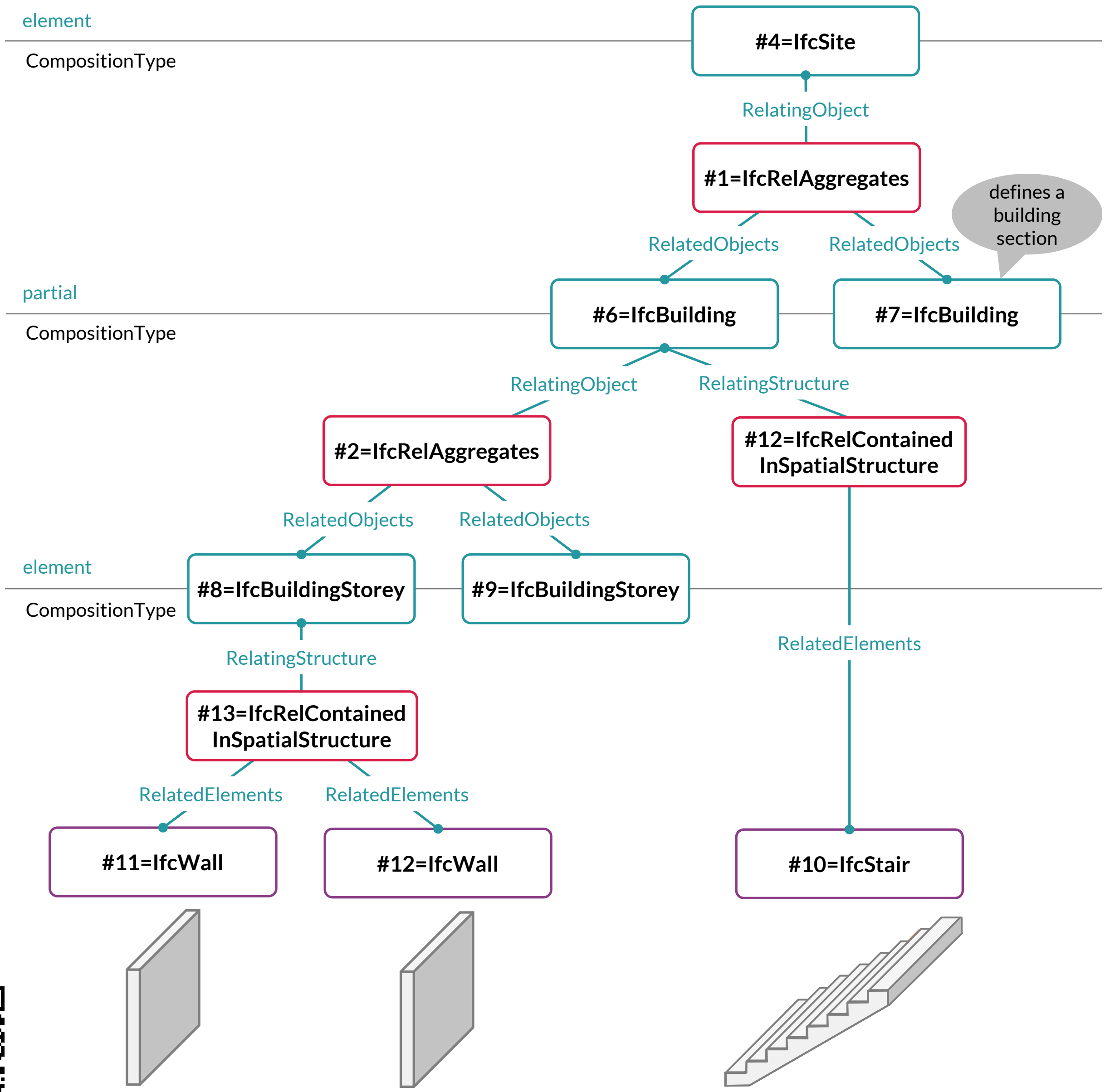


Fig. 3.29: Spatial relation in building construction (IfcRelContainedInSpatialStructure)

can only be assigned to one IfcSpatialStructure element. However, if a component, such as a cross-storey facade element, belongs to several spatial objects, an additional assignment can be made using the relation entity IfcRelReferencedInSpatialStructure. Elements of all child entities of IfcElement (e.g. IfcWall, IfcAlarm) can be linked to IfcSpatialStructure elements. In the example shown in Fig. 3.29 an instance of the entity IfcStair is linked to an element of the entity IfcBuilding and two instances of the entity IfcWall are linked to an element of the entity IfcBuildingStorey.

```
#90= IFCRELAGGREGATES('0Du7$nzQXCktKIPUTLFSAT',#12,$,$,#73,(#94));
...                                                  longitude / latitude
#94= IFCSITE('20FpTZCqJy2vhVJYtjuIce',#12,'Gel',$,$,#91,$,$,$,(51,28,57,28),(0,0,27,11),90,$,$);
...
#120= IFCRELAGGREGATES('2b_h_mYcGArd6glJG2Fmbt',#12,$,$,#94,(#134));
...
#134= IFCBUILDING('00tMo7QcxqWdIGvc4sMN2A',#12,'Geb\E4\ude',$,$,#132,$,$,$,$,$,$);
...
#158= IFCRELAGGREGATES('118jwqMnuwK1xuf97w7fU5',#12,$,$,#134,(#156));
....
#156= IFCBUILDINGSTOREY('2jkqT_bFr2PPoKaVDCZO3n',#12,'EG',$,$,#154,$,$,$,0.);
...                  linking of two components to the ground storey

#202= IFCRELCONTAINEDINSPATIALSTRUCTURE('2rCk01gaUDThQOhwaPveL7',#12,$,$,(#205,#71),#156);
...               linking of a component to exactly one storey
#205= IFCWALL('1dhyH71zv8Tf1O_s_jq3FI',#12,'Wand-010',$,$,#178,#200,'90-FBD2',.NOTDEFINED.);
```

Fig. 3.30: Spatial relation in STEP format

Spatial placement – building construction
The spatial relation described above enables the exact assignment of elements (e.g. IfcWall) to the entities/elements of the spatial structure (IfcSpatialStructure elements). Consequently, the spatial placement of the elements and the geometric referencing must now be defined. While the spatial placement does take place via the same IfcSpatialStructure elements, IfcLocalPlacement is used instead of relations. For this purpose, an origin (IfcSite) is defined, with each additional IfcSpatialStructure element receiving its own relative origin, referring back to the previous one. In the example presented in Fig. 3.31 and Fig. 3.32, the starting point is defined with IfcSite, containing the longitude and latitude. An X-Y-Z offset is then specified using IfcLocalPlacement and defines the global origin for all buildings on this site (IfcSite). The buildings (IfcBuilding) also have a relative origin, which can differ from the origin of the site (IfcSite) by an X-Y-Z offset. This process also applies to the relative origin of the storey, which normally comprises only a shift in the Z-axis (height). The relative origin of a component (e.g. IfcWall) in turn refers to the origin of the storey, where a shift in the X-Y-Z direction can also take place via IfcLocalPlacement. The geometric representation, i.e. the individual polypoints of the component (e.g. IfcWall), refer to the component origin.

Fig. 3.32 shows the spatial placement using an IFC STEP file example. In the example shown, the positions of the origin of IfcSite and IfcBuilding are identical (X-Y-Z offset = 0). The floor origin for the first floor is 3 metres above the building origin. IfcWall starts at a distance of X=8 m and Y=2 m from the storey origin.

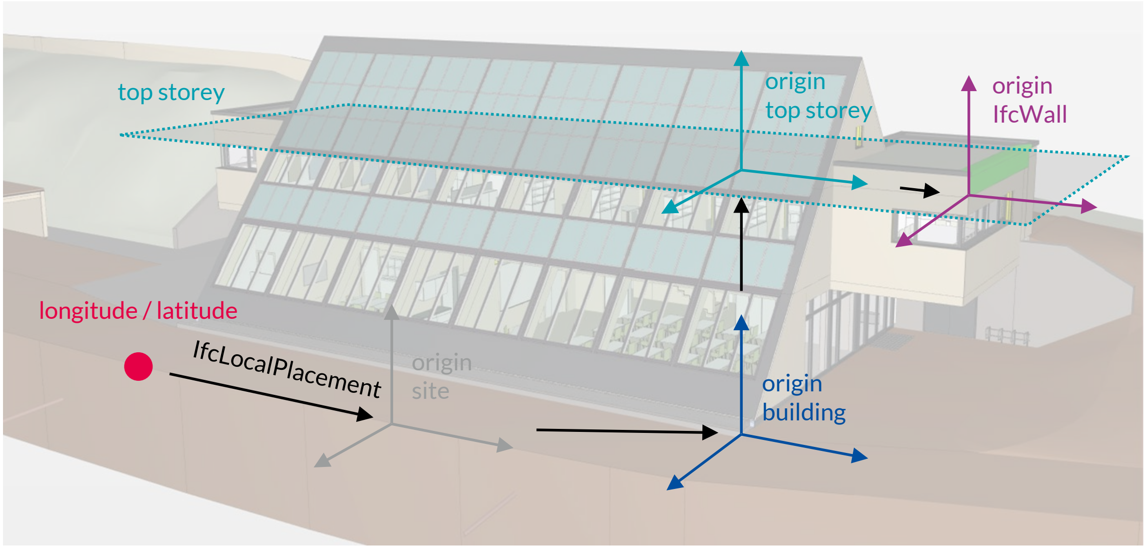


Fig. 3.31: Spatial placement in building construction

```
origin site
#84= IFCDIRECTION((1.,0.,0.));
#86= IFCDIRECTION((0.,0.,1.));
#88= IFCCARTESIANPOINT((0.,0.,0.));
#90= IFCAXIS2PLACEMENT3D(#88,#86,#84);
#91= IFCLOCALPLACEMENT($,#90);                    longitude / latitude
#94= IFCSITE('20FpTZCqJy2vhVJYtjuIce',#12,'Gel',$,$,#91,$,$,$,(51,28,57,28),(0,0,27,11),90,$,$);
...
origin building
#129= IFCCARTESIANPOINT((0.,0.,0.));
#131= IFCAXIS2PLACEMENT3D(#129,#127,#125);
#132= IFCLOCALPLACEMENT(#91,#131);
#134= IFCBUILDING('00tMo7QcxqWdIGvc4sMN2A',#12,'Geb\E4\ude',$,$,#132,$,$,$,$,$,$);
...
origin storey
#151= IFCCARTESIANPOINT((0.,0.,3.));
#153= IFCAXIS2PLACEMENT3D(#151,#149,#147);
#154= IFCLOCALPLACEMENT(#132,#153);
#158= IFCBUILDINGSTOREY('2jkqT_bFr2PPoKaVDCZO3n',#12,'1.OG',$,$,#154,$,$,$,0.);
...                                   origin component X=8/Y=2/Z=0 from
origin component
#175= IFCCARTESIANPOINT((8.,2.,0.));  project origin shifted
#177= IFCAXIS2PLACEMENT3D(#175,#173,#171);
#178= IFCLOCALPLACEMENT(#154,#177);
#205= IFCWALL('1dhyH71zv8Tf1O_s_jq3FI',#12,'Wand',$,$,#178,#200,'90-2',.NOTDEFINED.);
```

Fig. 3.32: Representation of spatial placement in STEP format

Spatial relations – linear structure (infrastructure)

The spatial relations of linear structures are based on the same principle as in building construction additionally supplemented by IfcSpatialStructure elements. The starting point for the spatial structure is, as before, IfcSite. An exemplary spatial relation of IfcBridge is presented in Fig. 3.33, with the same concept applicable to IfcRailway and IfcRoad. It is even possible to use a combination of these elements. The connection between the IfcSpatialStructure elements is made via the relation entity IfcRelAggregates. Components (e.g. IfcSignal) are assigned to the IfcSpatialStructure elements via the IfcRelContainedInSpatialStructure entity. Each component (IfcElement) may only be assigned to one IfcSpatialStructure element. Components can also be assigned directly to an IfcFacility, as is the case with IfcAlignment in Fig. 3.33. The child entities of IfcFacility and IfcFacilityPart can be further subdivided using the PredefinedType.

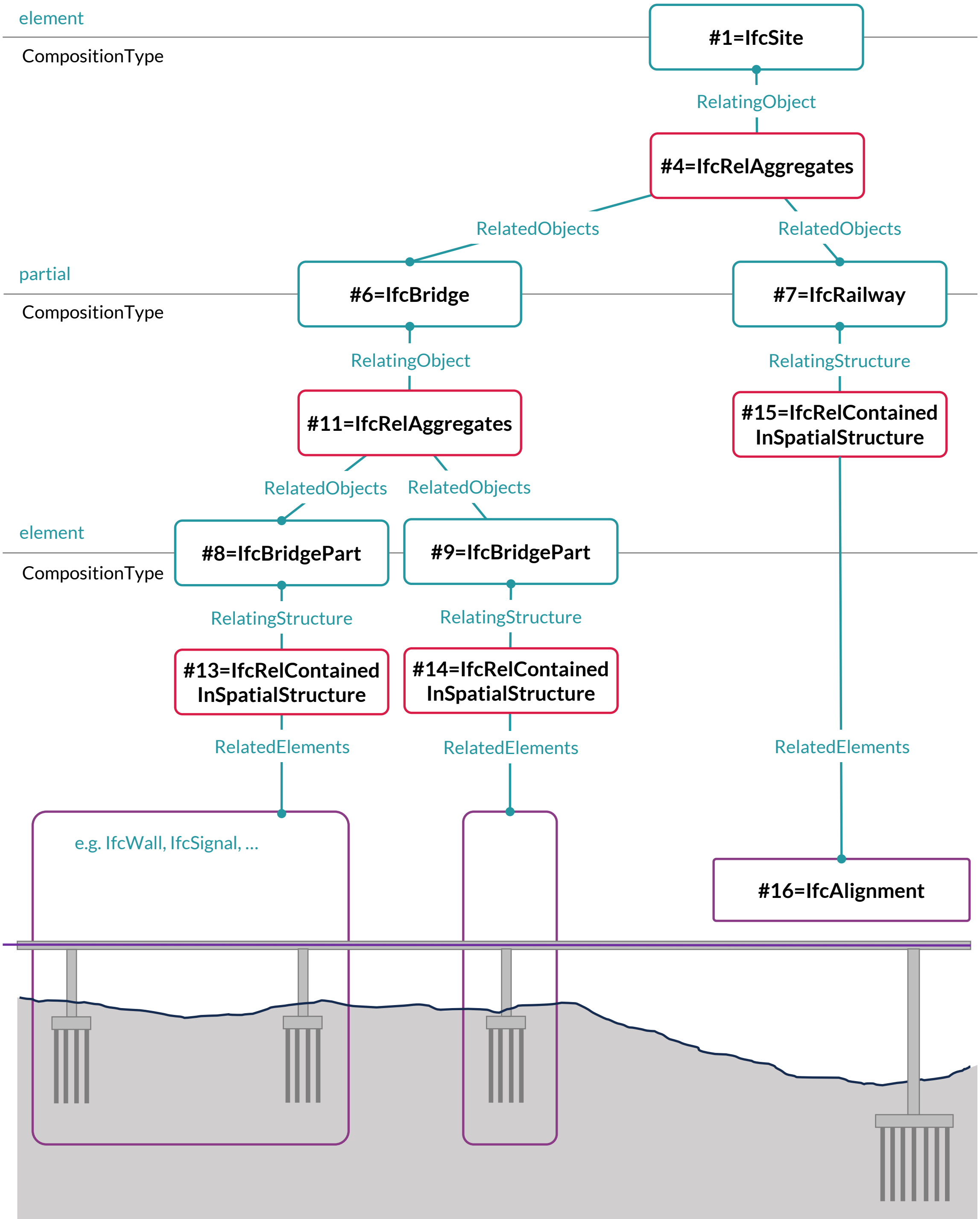


Fig. 3.33: Spatial relation of linear structures (infrastructure)

Spatial placement – linear structure (infrastructure)

This section deals with the spatial placement of linear structures, with the IFC4.3 data schema enabling various geometric representations and spatial placement options. One possible variant is described to illustrate the underlying concept.

The starting point for the spatial placement is IfcSite, which defines the origin of IfcRailway via IfcLocalPlacement. The origin of IfcRailway is in turn linked with IfcLocalPlacement to the origin of IfcAlignment (see ISO 19148). Up to this point, this corresponds to the concept from building construction.

IfcAlignment plays a crucial role in the spatial placement of linear structures such as roads and railways. It enables the digital representation of the geometric and geographical properties of roads, railways, and similar infrastructure elements. IfcAlignment itself is a line element that enables linear referencing of elements (e.g. IfcSignal) along this line. The element IfcSignal, for example, can be clearly localised along the IfcAlignment via IfcLinearPlacement and the specification of the length (*Distance along*). By further specifying horizontal and vertical offsets, the distance from IfcAlignment and thus the distance from the track axis can be added. These offsets are, in a two-dimensional space, orthogonal to the linear element (IfcAlignment). The *Distance along*, *OffsetVertical*, and *OffsetLateral* specifications are necessary for the clear localisation of IfcSignal along an IfcAlignment.

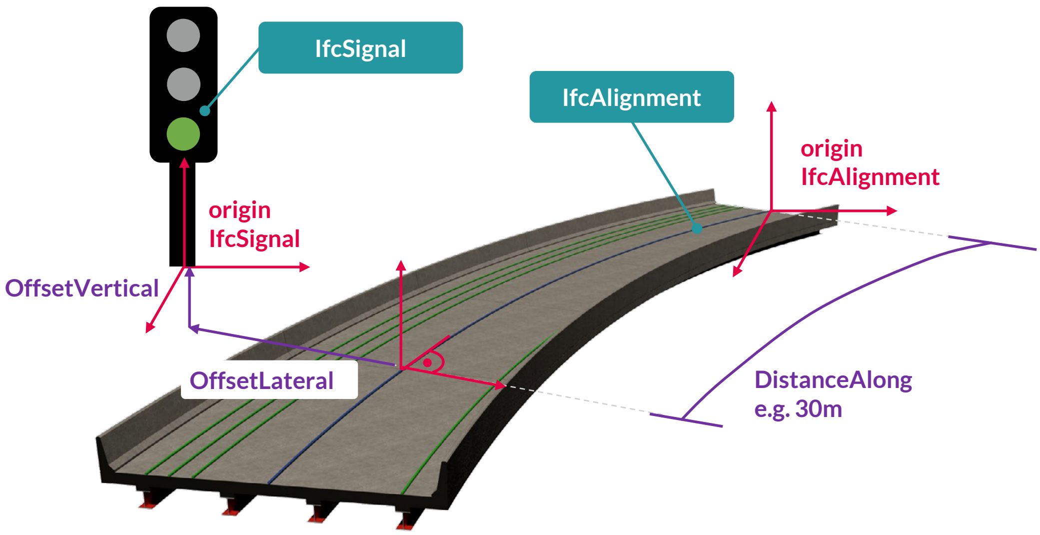


Fig. 3.34: Spatial placement of IfcSignal on an IfcAlignment

The geometric mapping of elements (e.g. IfcCourse) can refer to IfcAlignment in several points – e.g. start point and end point of IfcCourse. With additional geometric information (width and height), 3D volume objects can also be defined via referencing with IfcAlignment. It is important to note that referencing always takes place relative to the IfcAlignment and therefore the spatial course of the IfcAlignment is inherited. IfcCourse can be a component layer, e.g. an asphalt layer of a road.

IfcAlignment is therefore a central element of the spatial structure. In this example, IfcAlignment is not mapped directly as a 3D line in the IFC file but consists of several components within the IFC file constructed in a step by step fashion. In the *first step*, a horizontal ground plan is defined in a projected plane – a base line (track, horizontal projection). The elements refer to this when specifying the length (*Distance along*) for localisation. In a *second step*, the vertical alignment (i.e. a sequence of segments with constant gradients and smoothing segments with a variation in gradient) is added (longitudinal section). Subsequently, the cross slope can be defined by segments along the baseline effecting the rotation of the axis for the horizontal and vertical offsets. These three pieces of information make up the representation of IfcAlignment depicted in Fig. 3.35.

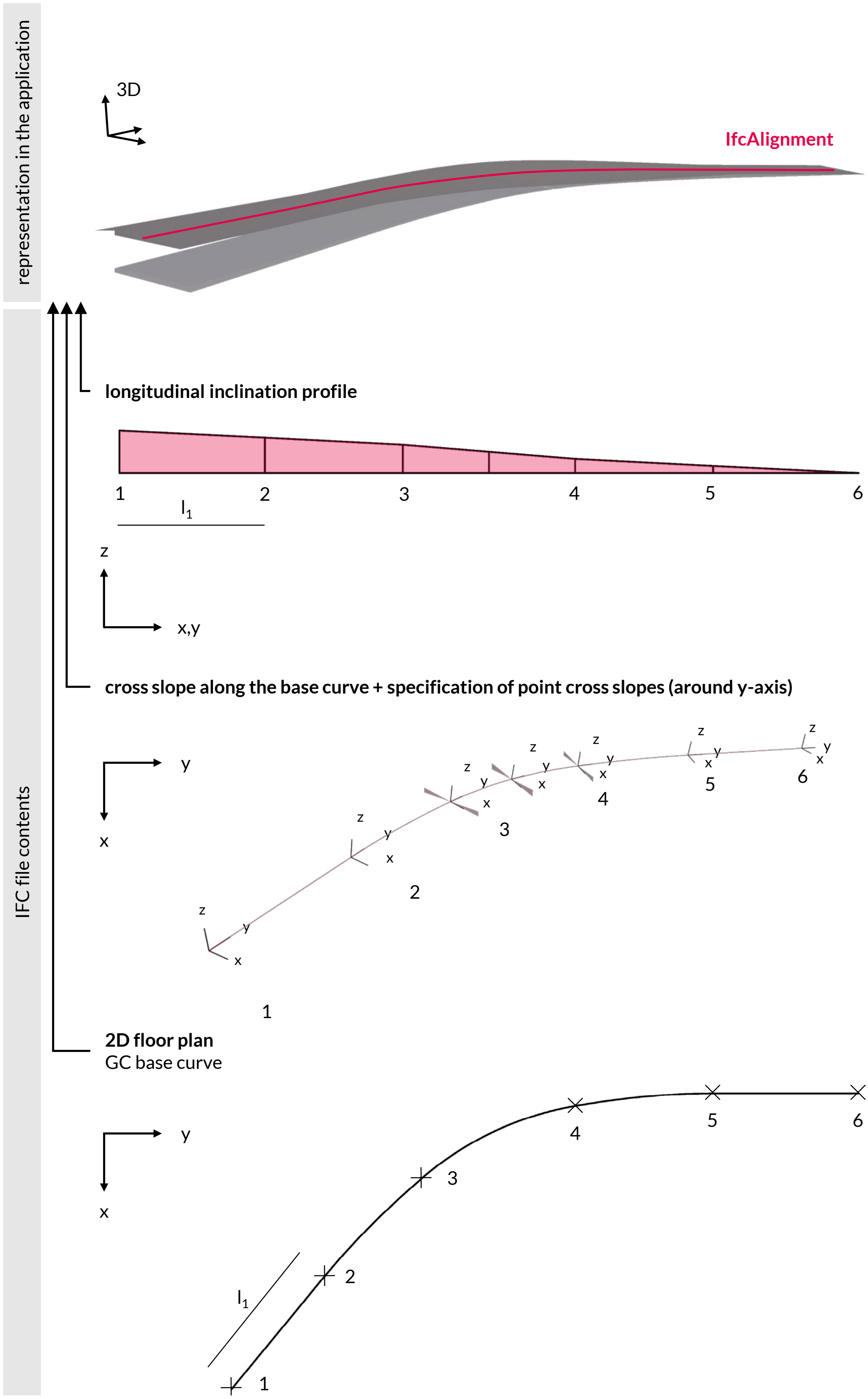


Fig. 3.35: Components of IfcAlignment

3.2.3.5 Resources – material

The assignment of materials to building components is an important part of every digital building model, as these are indispensable for, e.g. determining quantities, static verifications, and energy requirement calculations. Components (i.e. child entities of IfcElement) are linked to materials (i.e. child entities of IfcMaterialDefiniton) via the relation IfcRelAssociatesMaterial. The superordinate entity is IfcRelAssociates, whose various child entities establish relations to different project-external or project-internal information. IfcRelAssociatesMaterial, for example, refers to material information.

The relation between material and elements is illustrated in Fig. 3.36. IfcRelAssociatesMaterial has the attribute *RelatingMaterial* and, through the attribute inheritance of IfcRelAssociates, also the attribute *RelatedObjects*. The first attribute refers to child entities of IfcMaterialDefiniton, such as IfcMaterial or the IfcMaterialLayerSet required for composite materials. The second refers to child entities of IfcObjectDefinition, such as IfcWall, IfcBuildingElementPart. The IfcWall entity has the *HasAssociations* attribute due to attribute inheritance. The link is created using the attributes, see Fig. 3.37.

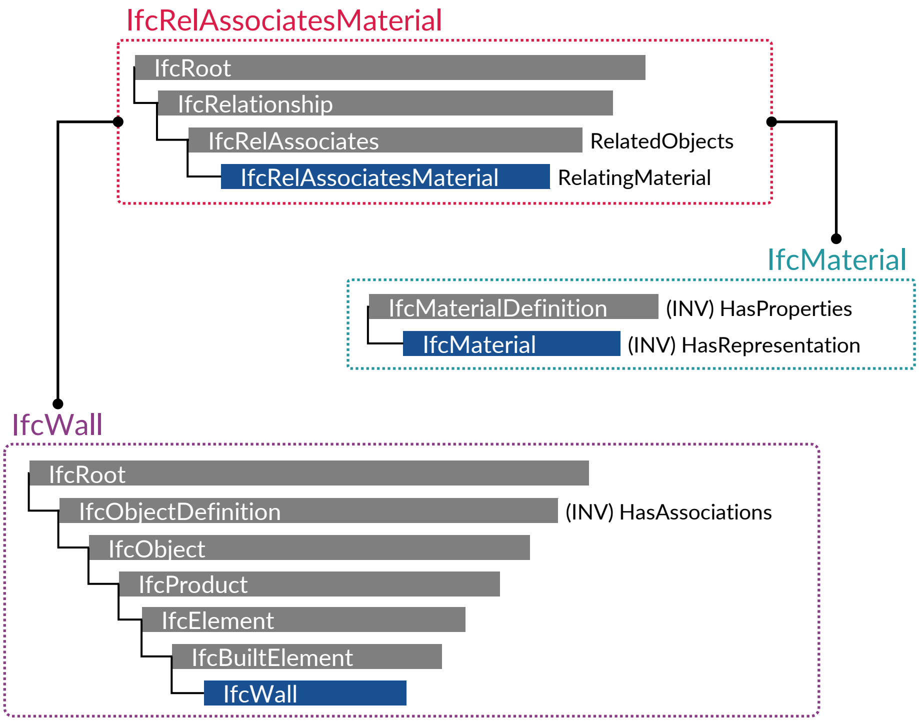


Fig. 3.36: Relation between IfcWall and IfcMaterial in the IFC data schema

The IFC data schema does not include any predefined material specifications. Materials can be named individually using the *Name* attribute. In addition, child entities of IfcMaterialDefiniton can contain further material properties, such as mechanical, thermal, or optical properties, via the *HasProperties* attribute. Furthermore, the IfcMaterial entity can be associated with representation information via the *HasRepresentation* attribute, such as hatching in the 2D representation or information for renderings.

In turn, properties can be assigned to the IfcMaterial via IfcMaterialProperties. These properties are grouped using IfcMaterialProperties. IfcMaterialProperties is comparable to IfcPropertySet for elements or IfcBuildingElementPart.

```
#256= IFCWALL('2C45vBrGbB_w_CB97snkya',#12,'WandBeispiel-001',$,$,#178,#244,
        '8C105E4B-D509-4BFB-AF8C-2C91F6C6EF24',.NOTDEFINED.);
...
#317= IFCRELASSOCIATESMATERIAL('3MbRGtiKSmHR0O2bTNcCnK',#12,$,$,(#256, #3560),#275);
...             assignment of the material to element #256 and element #3650
#275= IFCMATERIAL('Bauteil',$,$);
...          assignment of grouped properties to a material
#282= IFCMATERIALPROPERTIES('Pset_MaterialThermal',$,(#286,#293),#275);
...                  grouping of multiple properties
#286= IFCPROPERTYSINGLEVALUE('ThermalCon.',$,IFCTHERMALCONDUCTIVITYMEASURE(0.8),$);
#293= IFCPROPERTYSINGLEVALUE('HeatCapacity',$,IFCSPECIFICHEATCAPACITYMEASURE(800.),$);
```

Fig. 3.37: Relation between IfcWall, IfcMaterial, and properties in a STEP file

3.2.3.6 Resources – property

Additional information can also be added to elements (e.g. IfcWall, IfcAlarm) in the IFC data schema. This is done using properties (characteristics, e.g. fire resistance, structure number) and property sets. Properties can be freely defined using IfcProperty and its subordinate entities from the IfcPropertyResource schema. They are defined using a tuple of the form »Name-Value-Datatype-Unit«. The most used child entity of IfcProperty is IfcPropertySingleValue, within which exactly one value can be defined. For this case the template for properties is »*Name-NominalValue-Type-Unit*«, with an example being the property IfcLoadBearing of the entity IfcWall with the tuple »*Name: Load Bearing; NominalValue: YES; Type: Boolean*«. Another child entity of IfcProperty is, for example, IfcPropertyEnumeratedValue, where a value can be selected from predefined values, referenced via the *EnumerationValues* attribute. With IfcPropertyBoundedValue, an *UpperBoundValue* as well as a *LowerBoundValue* (upper and lower limit values, respectively) can be defined. Properties can be precisely controlled by declaring the type (*data type*) via child entities of IfcValue (e.g. IfcLabel or IfcVolumeMeasure) in terms of the content, units, or value ranges. In addition to the unit of measurement, the specification is usually also defined, e.g. a limitation to real numbers. The IFC specification further states the corresponding comprehensive SI units for all *types* (see QR code).

Individual properties are grouped in the IfcPropertySet (*property groups*) or IfcMaterialProperty, with the groupings organised thematically. Each element entity comprises at least one standard Pset, which is typically labelled with the suffix Common, e.g. Pset_WindowCommon. Some Psets are also assigned to multiple element entities at the same time, e.g. Pset_Warranty. Property sets that start with Pset_ are part of ISO 16739-1 and are therefore internationally standardised.

Individually created property sets must not begin with the prefix Pset_.

A property set is linked to an element via the IfcRelDefinesProperties relation and to the relation object via the *DefinesOccurrence* attribute of IfcPreDefinedPropertySet. The *IsDefinedBy* attribute enables all child entities of IfcObject to be linked to the relation object. All child entities of IfcObject can therefore carry property sets and properties. Child entities of IfcObject include IfcElement and IfcSite (Fig. 3.17) as well as IfcProject. An assignment to a subordinate entity of IfcElementType (e.g. IfcWallType) is also possible.

Fig. 3.38 summarises the various possibilities of defining a property for an IfcElement using the IfcElement IfcWall as an example. Properties can be assigned at *element level*, at *part level* (IfcBuildingElementPart), and *material level* via IfcPropertySet or IfcMaterialProperty. The most common variant is still the assignment directly to the element (IfcWall) via IfcPropertySet. IfcWallType is not mandatory – see Fig. 3.39, in which the IfcPropertySet is assigned directly to IfcWindow and not to IfcWindowType.

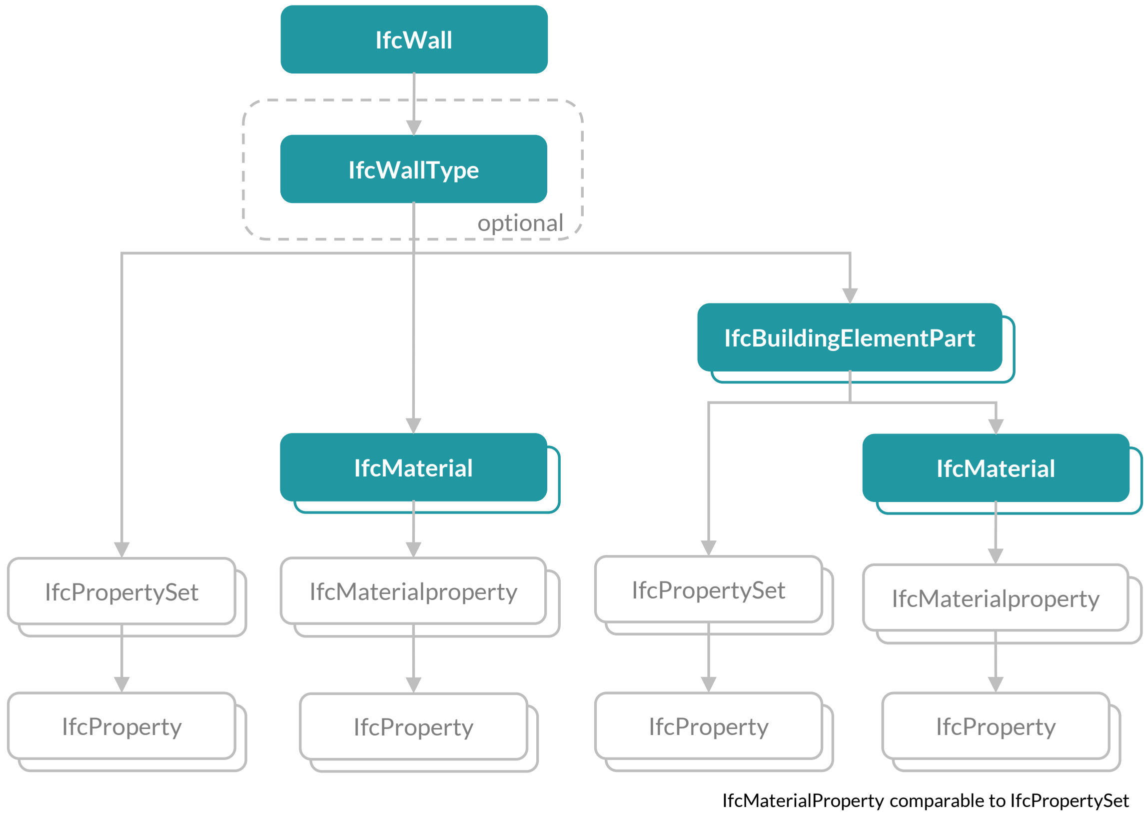


Fig. 3.38: Possibilities of IfcProperty for an IfcElement

```
#1155=IFCWINDOW('2QndTIV2X8589ermBtTWIq',#12,'Fenster5',$,$,#1002,#598,'9',.NOTDEFINED.);
#309= IFCRELDEFINESBYPROPERTIES('1c3NwR5m0zwE3x$OeygTQH',#12,$,$,(#1155 #300));
#300= IFCPROPERTYSET('204gSSj0jwfqIAswU_dsli',#12,'Pset_WindowCommon',$,(#288,#298));
#298= IFCPROPERTYENUMERATEDVALUE('Status',$,(IFCLABEL('EXISTING')),#296);
#288= IFCPROPERTYSINGLEVALUE('FireRating',$,IFCLABEL(''),$);
```

Fig. 3.39: Assignment of properties to the IfcWindow element

3.2.4 Epilogue

Section 3.2 provided an overview of the main options for assigning information in the IFC data schema. However, even more comprehensive functionalities, which have not been covered in this section, are available within the schema. One example is IfcGroup, which allows for the grouping of individual elements and thus structuring entire systems in the field of technical building equipment (MEP). Another useful element is IfcAnnotation, which can be used to display 2D graphics, dimensions, loads, internal forces, and texts in IFC. In principle, the IFC data schema enables an extensive information exchange between different software products. In cases where information (e.g. between software applications) cannot be transferred correctly, the reason does not lie within the (very well documented) IFC data schema, but rather within the import and export functionalities of the software application.

Student assistants Linda Ratz and Katharina Winkler supported the authors with their bachelor theses during the preparation of this section.

3.3 Model View Definition (MVD)

The Model View Definition (MVD) is an essential basis for describing transfer requirements and their technical implementation. The implementation and certification of IFC in BIM software applications is based on MVD.

3.3.1 Benefits of MVDs

An MVD is created in the context of a transfer requirement, e.g. the coordination of different domain models. It defines a customised restriction (subset) of the IFC specification (IFC schema). This restriction focusses on the requirements (exchange requirements) of the creator and recipient of the information. The review of the requirements is conducted based on an IDM (Information Delivery Manual) in accordance with ISO 29481. A limitation of the IFC specification by an MVD can affect the following content:

- Element classes and types and
- quantitiy sets, property sets, and properties.

The integration of infrastructure requirements into the IFC specification results in an increase in the number of element classes required. It is becoming increasingly impossible to implement the entire IFC specification for BIM software applications. Narrowing down an MVD makes this easier. It enables the functional scope of a BIM software applications to be tailored to the relevant requirements in the context of the MVD. The buildingSMART certification process (see QR code) for BIM software applications is therefore based on MVDs. MVDs have a harmonising or consolidating effect on the software market, as they represent a kind of template for the required range of functions for the creation, transfer, and interpretation of information. MVDs are published by buildingSMART International.

3.3.2 Established MVDs and their objectives

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

The geometric transfer options are not overly restricted and allow for flexible customisation. Model content can be transferred both with extruded geometry and with precise geometry (BREP – *Boundary Representation*). The transfer with extruded geometry allows the best possible native reuse in the target application. In contrast, transfer with precise geometry (BREP) enables 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, it is possible to evaluate/analyse a model layer by layer. A complex geometry is transferred triangulated in IFC2x3.

CV 2.0 has been certified for many BIM software applications on the market. Due to a lack of alternatives, it is sometimes also used on an interim basis for transport infrastructure projects, where intensive improvisation with IfcBuildingElementProxy is still required due to infrastructure element classes that are not yet available or implemented in the BIM software applications. The focus of the spatial structure to building construction or the imprecise handling of the coordinate system of the BIM software applications (in interaction with IFC) often causes a problem.

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

The *geometric transfer options* are *limited* (in contrast to CV 2.0) and focussed on the use case of model coordination. Model contents are transferred with precise geometry (BREP – *Boundary Representation*). This enables 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, it is possible to evaluate/analyse a model layer by layer. IFC4 ADD2 TC1 (4.0.2.1) now also offers the geometry description for BREP using NURBS. This is much more precise and space-saving (data volume) than the triangulation methods in IFC2x3.

RV 1.2 has now been certified for a larger number of BIM software applications on the market. RV 1.2 is also sometimes used for transport infrastructure projects due to a lack of alternatives. The focus of the spatial structure to building construction often causes a problem. The certification of RV 1.2 is less tolerant of errors, which is why the implementation of RV 1.2 certifications takes more time than for CV 2.0. However, it can therefore also be assumed that the implementation quality of BIM software applications is much more homogeneous.

3.3.3 Future MVDs and their objectives

As RV 1.2 implements the use case of model coordination in a much more focussed way than CV 2.0, at least a second MVD is required for IFC4 that supports the use case of model transfer (*interoperability*). This is necessary, for example, for the provision of the architectural model to structural engineers so that they can build their structural model. This is also necessary for handing over the model to the client at the end of the project so that the client can subsequently update changes to the structure in the model.

The Design Transfer View 1.1 (DTV 1.1) was developed for this purpose. It was created in the context of IFC4 ADD2 TC1 (4.0.2.1). The scope of DTV 1.1 focusses on the transfer of domain models between two BIM software applications – but only in one direction and not in a round trip. The geometric transfer options are limited (in contrast to CV 2.0) and focussed on the use case of model transfer. Model contents are transferred with extruded geometry and a limitation of their functionalities. This enables native reuse in the target application. DTV 1.1 is not yet certified for BIM software applications (as of January 2024).

Quantity Takeoff View 0.1 (QV 0.1) is an MVD that is aimed at the use case of model-based mass and cost determination. This is currently under development (*status draft*) and is not yet certified for BIM software applications (as of January 2024).

The Basic FM Handover View (FM) is an MVD that is aimed at the use case of transferring model information to FM (facility management) at the end of the project (see QR code). It was created in the context of IFC2x3 TC1 (2.3.0.1). FM has official status but is not yet established on the market and is not yet certified for BIM software applications (as of January 2024).

Product Library View 0.1 (LV 0.1) is an MVD that is aimed at the use case of transferring digital product information (*DataTemplates*). This is currently under development (*status draft*) and is not yet certified for BIM software applications (as of January 2024).

Other MVDs under development can be found on the buildingSMART International website (see QR code).

3.4 BCF comments

BCF comments represent questions and problems relating to specific model elements and serve to communicate defects between the information management functions. In the ISO and buildingSMART standards, BCF is the data interface for communication - without transporting specific model elements.

BCF comments (or issues) always include:

- the GUID (*Globally Unique Identifier*),
- the assigned name,
- stored viewpoint(s) with camera position on selected model elements, visibility, and colouring of model elements (IFC coordinates),
- Images (in relation to the viewpoints),
- Annotations in 3D space,
- Description, date, author, recipient, group assignment (e.g. discipline or information management functions),
- Comments (author, date, focus),
- attached files and
- the status (e.g. open, closed).

With BCF 3.0, it is also possible to transfer individual additional properties/information using a BCF. On this basis, BCF can also be used to manage more complex use cases in which more comprehensive declarations need to be exchanged – e.g. the use case of connection coordination. In principle, it is also possible to transfer model properties using BCF – a function that is being launched under the term »BIM snippets«. However, this requires the corresponding functional scope of the BIM software applications involved.

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 respective software applications. BCF are used by all information management functions. Their main function is quality assurance of model management, as they both communicate and document problems. However, BCF are also used in coordination cases between BIM domain coordination and BIM modellers to be able to coordinate specific questions on model and planning content (see Fig. 3.40).

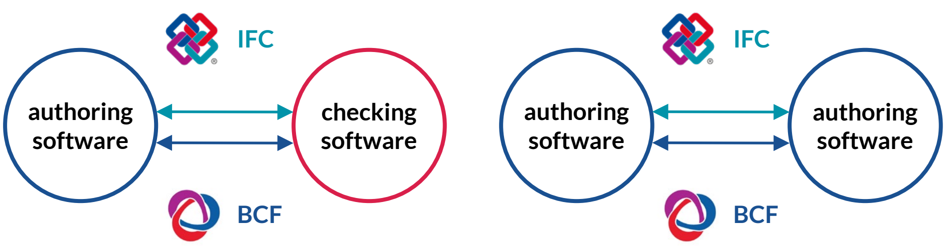


Fig. 3.40: Data exchange between BIM software applications

BCF can also be used in different ways during the service phases:
in the design phase:

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

in the tender and award (procurement) 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 articles/materials and coordinating replacement products, and
- collection of last-minute information for handover to the client/owner/operator.

in the operation phase:

- Information on handover models in the event of changes to the system and its many elements during operational use and
- owner's notes on necessary improvements.

The comments in BCF comments should always be precise, brief, and neutral. The selected viewing positions on the model content should always be clearly displayed (through visibility and colouring). The status of the BCF comments should also always be kept up to date. The status should be set to »closed«, especially when problems have been solved. These guidelines enable a good workflow between all project participants and ensure that the BCF functionality can also be used clearly outside of your own software applications.

Regardless of the time and use, BCF comments should always be exchanged via a defined platform in the interests of transparency and consistency. This can be the CDE of the respective project or an additional web-based collaborative platform intended for this purpose. A good platform always provides a good overview of the status of a project via its functionalities and visualisations – this can be mapped via the BCF comments. By assigning them to groups (information management functions and domain models), responsibilities in the problem areas and the status of all BCF comments, not only can individual critical points be identified, but critical project performance can also be recognised in time.

The following images show typical BCF comments. The problem description, status, due date, and responsibility are shown in the centre. The corresponding views (viewpoint with camera position on selected model elements) can be seen on the right.

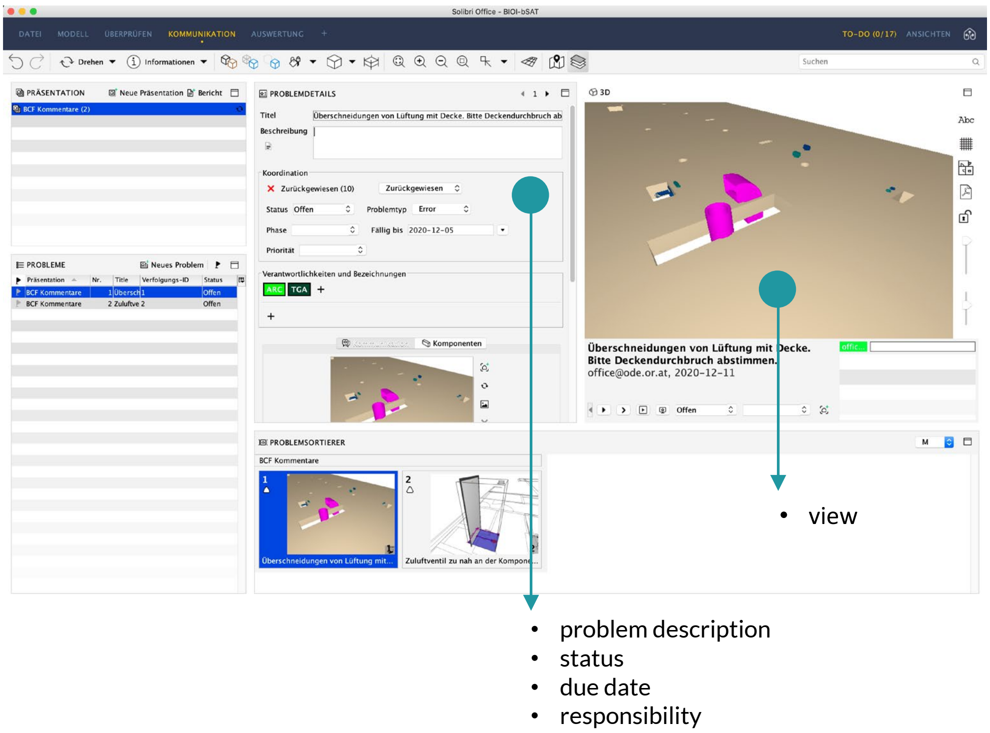


Fig. 3.41: Example for BCF – overlap of ventilation with ceiling

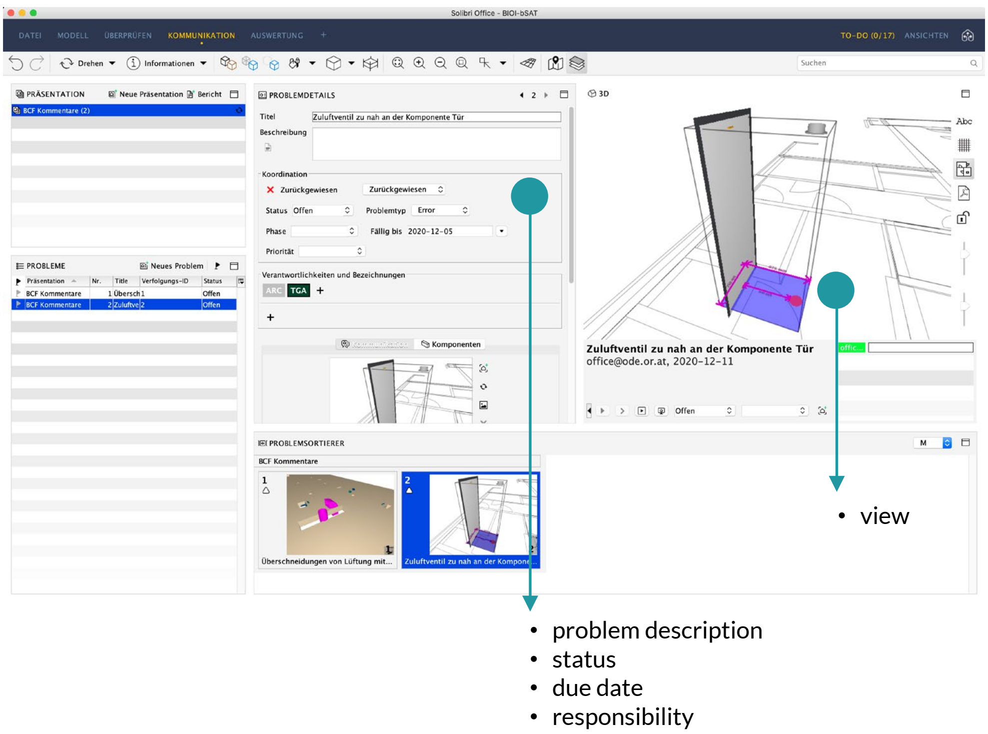


Fig. 3.42: Example of BCF – components too close to each other

3.5 Common Data Environment (CDE)

The *Common Data Environment* (collaboration platform) is an essential basis for handling collaboration during project implementation. A CDE is usually provided by the client in projects. In the best-case scenario, a professional client processes its entire portfolio on a CDE and thus reduces set-up costs while benefiting from the advantages of centralised data storage and uniform structuring.

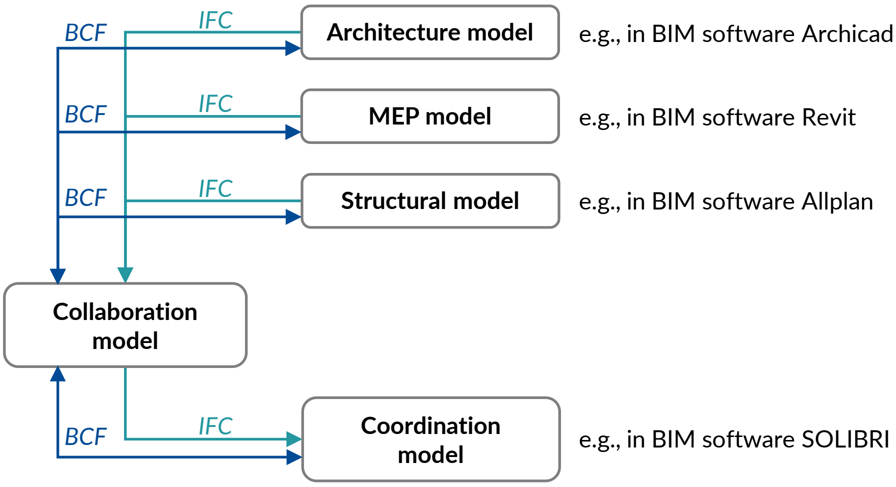


Fig. 3.43: Data exchange between models

CDE is generally understood to mean a web-based platform for collaboration between the entire planning team – this enables collaboration between different software applications. Integrated collaboration platforms are used to carry out collaboration within a specialist discipline – these enable collaboration within a specific application and offer possibilities such as real-time collaboration and joint work down to element level or even feature level.

3.5.1 Development history

In 2007, the British BIM standard PAS 1192 standardised the function and structure of a CDE for the first time. Collaboration on a file basis was assumed – as can be realised with simple file sharing platforms (e.g. Nextcloud). The status of a file was declared via its assignment 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 adopted from PAS 1192 – as this forms the basis of the ISO 19650 series.

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

The weak point of the CDE in practice to date is the high effort to provide data. Until now, the parties involved have had to upload documents, plans, models (IFC) and model comments (BCF) to the CDE manually and declare them accordingly. This sometimes (product-dependent) complex work is time-consuming and error-prone. The following figures describe the typical effort for providing (Fig. 3.44) model information on the CDE and checking and providing the test results (Fig. 3.45).

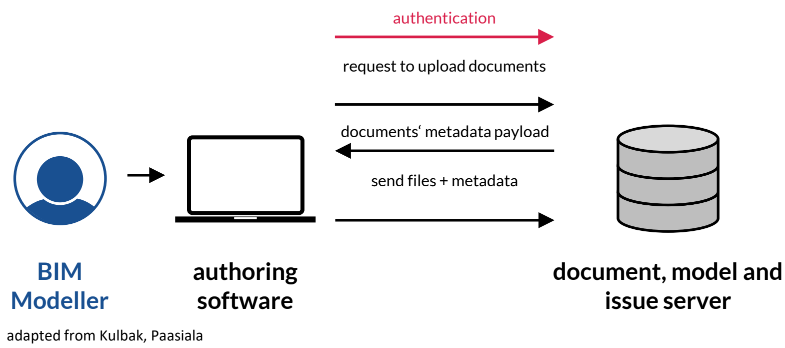


Fig. 3.44: CDE communication BIM Modeller

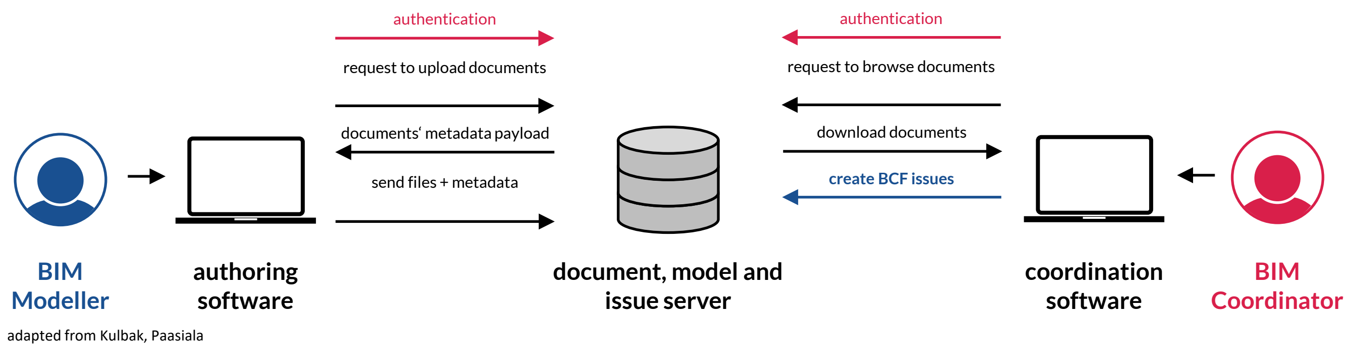


Fig. 3.45: CDE communication BIM Modeller and BIM Coordinator

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

The exchange is no longer managed at file level but based on database-based web services. Manual declaration is no longer necessary; only changes are transferred. This optimises the data volume and therefore the transmission time. Fig. 3.47 describes the reduced effort for model-based communication.

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

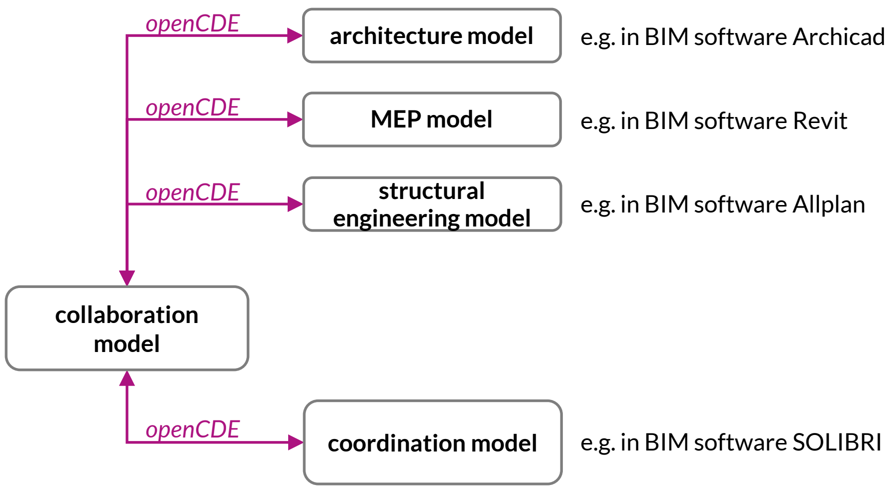


Fig. 3.46: Data exchange between models with openCDE

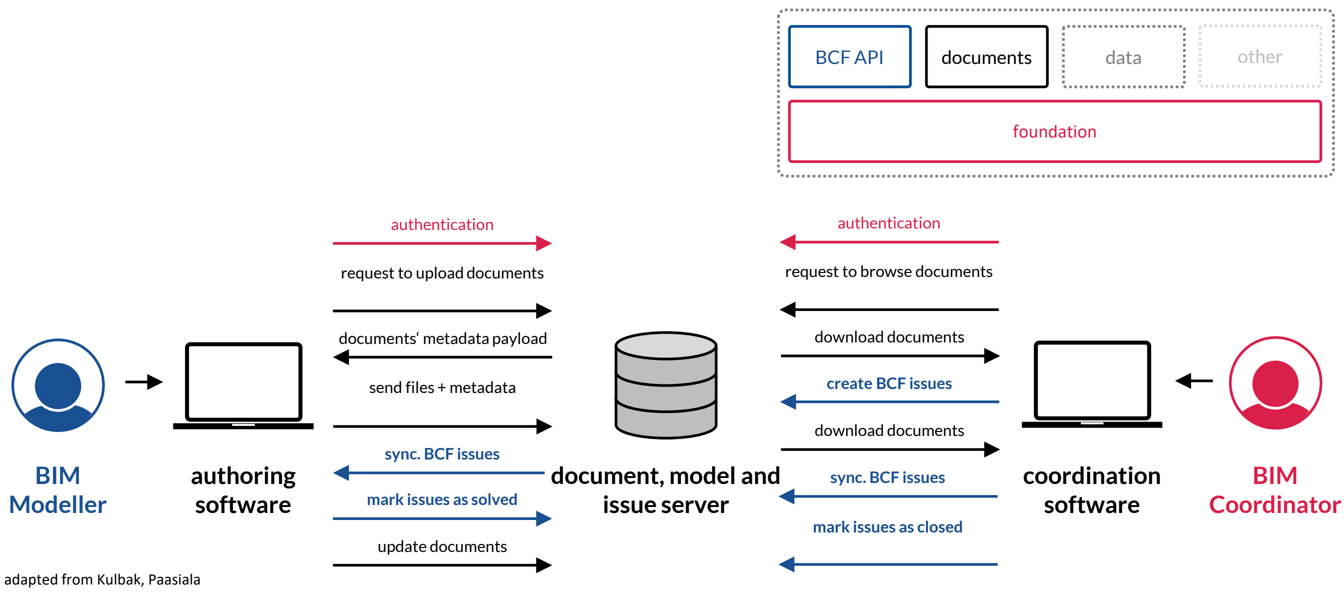


Fig. 3.47: openCDE communication BIM Modeller and BIM Coordinator

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 different projects and their respective project teams;
  Advantage: sfast availability of information, clear retrievability of information, central analysability of all projects (for portfolio);
- ensuring the necessary data security through encrypted data transfer, user authentication, multi-client capability, role-based user concept;
  Advantage: Ensuring the necessary discretion regarding sensitive information, guaranteeing compliance with legal requirements;

- the consistent and standardised structuring of all project information (also across projects);
  Advantage: simplified project management due to easier analysability of the project status, easier comparability of project information;
- the standardised, controlled implementation of project processes (also across projects);
  Advantage: simplified project management thanks to predefined processes with clear responsibilities and transparent communication;
- fast and accurate review of the project status using predefined key values (also across projects);
  Advantage: simplified project management;
- easier identification of relevant project content/processes for archiving or compact transfer of relevant project content/processes for archiving at the end of the project, and
- facilitated identification of relevant project content/processes for operational management or compact transfer of relevant project content/processes to operational management or AIM at relevant times.

3.5.3 Criteria for a CDE

A CDE is a central data room for all project information. Its operation is therefore subject to data protection criteria and the warranty claims to be considered. The CDE is often provided on the provider's hardware, as clients do not have access to the necessary technical performance and security in their own IT structures. In such cases, the client must check both the conformity of the provider's service under data protection law and its conformity with the required warranty claims regarding availability, reliability, physical access, dependency on third parties, etc. Such requirements often conflict with the client's specifications. Such requirements often conflict with currently advertised cloud offerings. Here, the advantages and disadvantages must be carefully examined.

3.6 Level of Information Need (LOIN) and level of detail (LOG, LOI)

Paul Curschellas (guest author), Tina Krischmann

This section describes the method for defining and determining the level of information need required by the actors involved at a specific point in time. The method for defining the Level of Information Need is standardised in EN 17412-1.

The ISO 19650 series of standards identifies the processes and roles in the provision of information from the perspective of the information receiver (appointing party) and the information supplier (appointed party). In addition, EN 17412-1 (Building Information Modelling – Level of Information Need – Part 1: Concepts and Principles) provides the methodological basis for defining the level of information need.

In the context of information management, the Level of Information Need (LOIN) describes the client's requirement for information regarding the depth of geometric and alphanumeric information, as well as the expected documentation, such as the delivery by the provider of information. The rules for defining the level of information need are an essential part of the EIR and BEP regulations and part of the client's requirements. They serve as the basis for a smooth process flow within a project – however, the gradations as such are not standardised. Rather, it is the respective conditions, the project goals, application goals and the use cases based on these that form the basis for narrowing down and defining the level of information need.

The information requirements of the LOIN are therefore derived from the needs of the use cases that are conducted at certain points in the project. The LOIN comprises the geometric (LOG) and alphanumeric (LOI) definitions of the domain models as well as the associated necessary documentation (DOC).

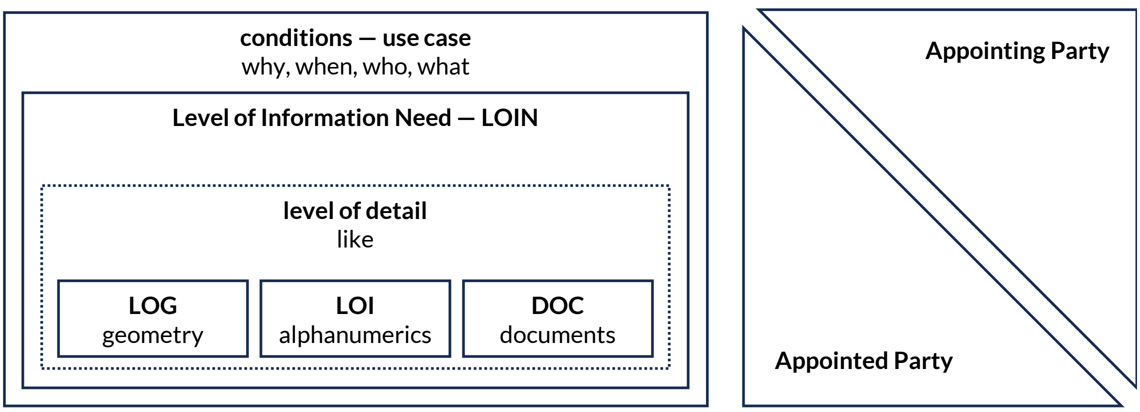


Fig. 3.48: Definition of the Level of Information Need (use cases) is answered by the level of detail (2 steps)

By answering the needs of the individual use cases of the rules and regulations, it is possible to avoid the geometric modelling and the information of the model elements with the alphanumeric information being too much (thus unnecessary) or too little (thus overlooked) in the project.

The development, provision, coordination, and maintenance of the geometric and alphanumeric elaboration in the various domain models and the associated documentation are thus subject to a controlled environment that always offers demonstrable benefits via the use cases. This type of communication of information requirements offers the advantage right from the start of the project that the client and contractor have a good insight into the scope of the project and the effort involved can be easily estimated and agreed by the parties involved (contracts and provisions).

3.6.1 Methods in EN 17412-1 vs. established practice

Practical experience has shown that the acronyms »LOG« and »LOI« and the definitions of their »classes 100–500« are not really suitable for precisely describing an expected delivery object. The definitions for model-based collaboration have so far been made without deriving and recording the requirements, the process, and the responsibilities in relation to the use case. This could lead to inconsistencies in the coordination of those involved and opened room for interpretation in the regulations made. This meant that the information required for a building could not be provided reliably and without contradictions.

The previous provision of the LOG and LOI levels of detail simplifies communication for model data implementation and data delivery. However, it is strongly advised against basing the level of information need solely on this or agreeing this contractually. The clear recommendation here is to derive this from the use cases in the project-related rules and regulations.

The method for determining the LOIN in EN 17412-1 is based on two steps:

Step 1: Definition of the prerequisite
why, when, who, what

Step 2: Definition of the Level of Information Need for geometry, alphanumeric, and documentation
how

The steps required to determine the level of information need according to this method are described below.

3.6.2 Procedure for determining the Level of Information Need

Step 1 – Prerequisites

To determine the LOIN in line with requirements, the necessary prerequisites must first be clarified. However, they are not themselves part of the LOIN.

Definition of the prerequisites (why, when, who, what):

Why The purpose and intended use, applications, and utilisation, form the basis of the information supply.
When Milestone information delivery, time at which a specific delivery object is expected.
Who Actors in the project who are information receivers (appointing parties) or information creators (appointed parties).
What Information content that is defined at a certain level of information need.

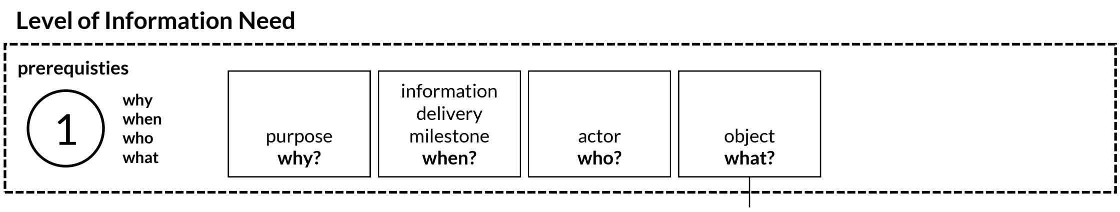


Fig. 3.49: Step 1 in the definition of the Level of Information Need – prerequisites (Source: Bauen digital Schweiz, see QR code)

Step 2 – Level of Information Need
In the second step, the »how« or the definition of the level of information need, the type of information must be designated. In SN EN 17412-1:2020, three categories are used to designate the type (characteristic) of information delivery. The aim is to provide information that can be interpreted by machines and humans.

1. Geometry	Information defined as detail, dimension, position (localisation), visual appearance and parametric.
2. Alphanumeric	Information that is identified via unique keys (source) and labelled via attributes and properties.
3. Documentation	Information that represents the delivery result at a specific point in time.

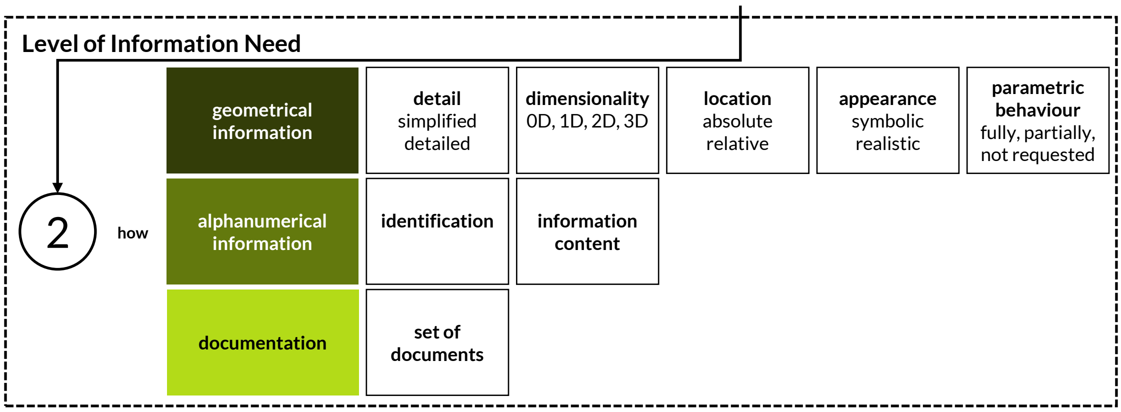


Fig. 3.50: Method for defining the »Level of Information Need« in two steps according SN EN 17412-1 (Source: Bauen digital Schweiz, see QR code)

3.6.3 Processing in practice (in a project)

Over the course of the project, the requirements for the level of information need, geometric information (LOG), alphanumeric information (LOI) and documents (DOC) can increase and decrease. This is related to the requirements of the respective use case, such as approval planning, cost determination, tendering, production and assembly planning, documentation for operation (FM) at the time the as-built model is handed over to facility management. Based on a use case (= »why«), the model elements concerned (element classes = entities) are assigned the necessary requirements (= »what«) in terms of their geometry (LOG) and alphanumeric (LOI), which they must represent at a certain point in time (= »when«). The production of this depth of information is the responsibility of the responsible actor (= »who«).

The LOG and LOI levels of detail therefore contain the geometric and alphanumeric content requirements for the domain models for data exchange and further use of the model data. The requirements are transferred to the respective authoring software and implemented in the model data (= creation of the model content). Depending on the use case, the depth of the alphanumeric information content may exceed that of the standard IFC data structure, in which case separate individual property sets and properties must be defined.

Ideally, all the content of the documentation (DOC) is derived from the models. This should be the case on a one-to-one basis (1:1) for the information on geometry and alphanumeric derived from the model. However, the documentation contains additional information, which is generally provided via the models. This aspect must be considered in project delivery activities by ensuring quality assurance and the higher-level review process of the documentation in the project through the controlling function of people and their roles in the project.

Both LOG and LOI serve as an important basis for quality assurance and can be checked automatically against the documents in the models. They form the basic framework on which the check content in the checking software is based depending on the phase (coordination and control).

3.6.4 Application example

The (abstract) use case for the creation of the fire protection concept is used here as an example for the definition of the Level of Information Need (LOIN) of a specific use case, as this allows a manageable presentation in terms of scope.

Step 1 – definition of the prerequisite (why, when, who, what)

- **Use case**: coordinated model-based fire protection concept.
- **Objective and intended use (why)**: coordination and documentation of the planned fire protection measures (structural and technical).
- **Milestone (when)**: at the end of the service phase/planning phase 3.
- **Participants (who)**: shared authorship between architecture (ARC specialist model management) and fire protection planning (BRP content).
- **Information content (what)**: Provision of the information required to coordinate the planning and documentation of the requirements from the fire protection planning. Model-based planning with derivation and creation of the necessary documents for fire protection planning.

Schritt 2 – Level of Information Need (how)

Geometrie – LOG: All elements must be assigned to a specific and correct classification system in accordance with the required exchange format (in this case and unless otherwise required, the IFC specifications – see QR code). Arbitrary building elements (= IfcBuildingElementProxy) are best excluded and should only be used in models in exceptional cases and in consultation with BIM management.

The required model elements are at least: rooms (including their spatial relation to storeys, buildings), walls, doors, stairs, columns, fire extinguishing equipment, fire alarms, emergency exit signs.

The modelling specifications correspond to the detailed resolution that follows the coordination and documentation of the planned fire protection measures:

- All elements are to be localised in their original storeys.
- Structural elements must be created in accordance with the component catalogue.
- Element-based modelling is used – this means that the use of »generic« elements is not recommended.
- The model elements required to create the planning documents are developed. Of course, these components should be related to phases and only be recorded geometrically as precisely as necessary.

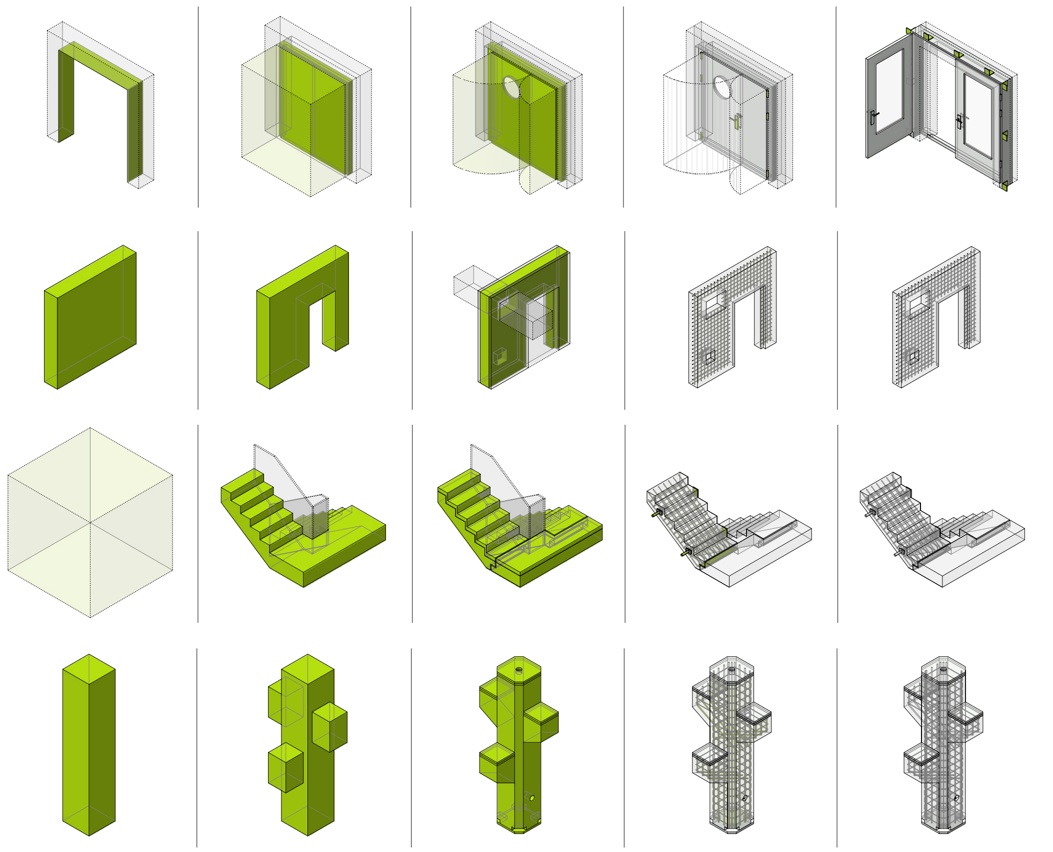


Fig. 3.51: Levels of detail for components: door (top row), interior wall (2. row), stairs (3. row), and column (bottom row) (Source: Bauen digital Schweiz, see QR code)

Alphanumeric – LOI: The model elements walls, doors, stairs, columns, fire extinguishing equipment, alarms, emergency exit markings are to be transmitted with the alphanumeric information content for planning and coordination:

- Property / terrain:
  - IfcSite – unique labelling in the Name attribute
- Building:
  - IfcBuilding – unique labelling in the Name attribute
- Storey:
  - IfcStorey – unique labelling in the Name attribute
- Room / space:
  - IfcSpace – PredefinedType: SPACE, INTERNAL

- Wall:
  - IfcWall – PredefinedType: STANDARD, SOLIDWALL, PARAPET, PARTITIONING
- Door:
  - IfcDoor – PredefinedType: DOOR, GATE
- Stairs:
  - IfcStair – all PredefinedTypes
- Column:
  - IfcColumn – all PredefinedTypes
- Fire extinguishing equipment:
  - IfcFireSuppressionTerminal – PredefinedType: FIREHYDRANT, USERDEFINED = WALLHYDRANT
- Fire alarm:
  - IfcAlarm – PredefinedType: ALARM
- Emergency exit labelling (exit signs):
  - IfcBuildingElementProxy – PredefinedType: USERDEFINED = FIREEXITLABELING

Informationsbedarfstiefe WIE				Verantwortlich WER		Phase WANN	Struktur WAS											Anwendungsfall WARUM
Merkmal/Attribut	Wertetyp	Wertebereich	Verortung und Benennung im IFC-Fachmodell	Autor Geometrie (LOG)	Autor Alphanumerik (LOI)	Projektphase	Grundstück IfcSite	Gebäude IfcBuilding	Geschoss IfcBuildingStorey	Raum IfcSpace	Wand IfcWall	Tür IfcDoor	Treppe IfcStair	Stütze IfcColumn	Feuerlöscheinrichtungen IfcFireSuppressionTerminal	Feuermelder IfcAlarm	Notausgangkennzeichnungen IfcBuildingElementProxy PredefinedType: USERDEFINED = FIREEXITLABELING	Abgestimmtes modellbasiertes Brandschutzkonzept
Name	IfcLabel	Auswahl/Benennung gem. Konvention Projekt	*IfcSite.NAME*	ARCH	ARCH	2	X											X
Name	IfcLabel	Auswahl/Benennung gem. Konvention Projekt	*IfcBuilding.NAME*	ARCH	ARCH	2		X										X
Name	IfcLabel	Auswahl/Benennung gem. Konvention Projekt	*IfcBuildingStorey.NAME*	ARCH	ARCH	2			X									X
FireExit	IfcBoolean	WAHR oder FALSCH	*Pset_SpaceFireSafetyRequirements.FireExit*	ARCH	BRP	3				X								X
FireExit	IfcBoolean	WAHR oder FALSCH	*Pset_DoorCommon.FireExit*	ARCH	BRP	3						X						X
FireExit	IfcBoolean	WAHR oder FALSCH	*Pset_StairCommon.FireExit*	ARCH	BRP	3							X					X
FlammableStorage	IfcBoolean	WAHR oder FALSCH	*Pset_SpaceFireSafetyRequirements.FlammableStorage*	ARCH	BRP	3				X								X
AirPressurization	IfcBoolean	WAHR oder FALSCH	*Pset_SpaceFireSafetyRequirements.AirPressurization*	ARCH	BRP	3				X								X
SprinklerProtection	IfcBoolean	WAHR oder FALSCH	*Pset_SpaceFireSafetyRequirements.SprinklerProtection*	ARCH	BRP	3				X								X
SprinklerProtectionAutomatic	IfcBoolean	WAHR oder FALSCH	*Pset_SpaceFireSafetyRequirements.SprinklerProtectionAutomatic*	ARCH	BRP	3				X								X
FireCompartmentNumber	IfcLabel	Nummerierung fortlaufend	*Mset_SpaceFireSafetyRequirementsSpecific.FireCompartmentNumber*	ARCH	BRP	3				X								X
FireRating	IfcLabel	Auswahl gem. nationaler Vorgaben	*Pset_WallCommon.FireRating*	ARCH	BRP	3					X							X
FireRating	IfcLabel	Auswahl gem. nationaler Vorgaben	*Pset_DoorCommon.FireRating*	ARCH	BRP	3						X						X
FireRating	IfcLabel	Auswahl gem. nationaler Vorgaben	*Pset_ColumnCommon.FireRating*	ARCH	BRP	3								X				X
Compartmentation	IfcBoolean	WAHR oder FALSCH	*Pset_WallCommon.Compartmentation*	ARCH	BRP	3					X							X
SelfClosing	IfcBoolean	WAHR oder FALSCH	*Pset_DoorCommon.FireRating*	ARCH	BRP	3						X						X
SmokeStop	IfcBoolean	WAHR oder FALSCH	*Pset_DoorCommon.FireRating*	ARCH	BRP	3						X						X
HasDrive	IfcBoolean	WAHR oder FALSCH	*Pset_DoorCommon.FireRating*	ARCH	BRP	3						X						X
ExtinguishingMedia	IfcLabel	ND; Wasser; Kohlendioxid; Schaum; Pulver; Fettbrand; Metallbrar	*Mset_FireSuppressionTerminalTypeSpecific.ExtinguishingMedia*	ARCH	BRP	3									X			X
TypeOfAlarm	IfcLabel	ND; Feuermelder; Einbruch; CO2; etc.	*Mset_AlarmTypeSpecific.TypeOfAlarm*	ARCH	BRP	3										X		X
TypeOfFireExit	IfcLabel	ND; Ausgang; Fluchtweg	*Mset_BuildingElementProxySpecific.TypeOfFireExit*	ARCH	BRP	3											X	X

Fig. 3.52: Element plan; Level of Information Need – required alphanumeric information per component

Documentation – DOC: Provision of documentation for the coordination of planning and documentation in accordance with the requirements of the fire protection planning. The documents must be prepared and provided in accordance with the coordination between architecture and fire protection:

- Planning documents:
  - Site plan and
  - floor plans, sections, and views for each storey:
    - Contents are to be derived from the domain model (.dwg and .pdf). Labelling (e.g. emergency exits) must be shown separately in legible form in the plans in accordance with the model element positioning. Value contents (e.g. fire resistance class *FireRating*) must be noted separately in legible form in the plans

- Explanatory report:
  - Fire protection concept and
- Certificates from the manufacturer regarding fire protection labelling
  - System verification.

3.6.5 Terms in the application

Use case: describes the execution of one or more specific processes by responsible parties according to defined requirements to support the fulfilment of one or more objectives using the BIM method (ISO/DIS 29481-3:2021, 3.3).

Level of Geometry (LOG): defines the geometric information of a model. The geometric accuracy increases as the project progresses.

Level of Information (LOI): describes the content-related alphanumeric information of a model. The attributes and properties of the objects to be used are defined for this purpose.

Documentation (DOC): describes which information is provided by means of the documentation. The individual documents are listed accordingly.

BIM model plan and BIM element plan:

The *BIM execution plan BEP* is supplemented by the *BIM model pla*n and the *BIM element plan*. The BIM model plan graphically defines all topological model requirements. The BIM element plan defines all information requirements.

BIM model plan: The BIM model plan supplements the *BIM execution plan* and describes all geometric model requirements, such as topology, planes, units, coordinate origin, insertion point, georeferencing and export settings.

BIM element plan: The BIM element plan is used to record the content of the required model elements in the BIM models. It describes the information requirements in a phase-orientated and component-orientated manner depending on the selected use cases. The labelling conventions to be used by the parties involved, such as the overview of the types/model components used, are mapped. The element plan applies to the disciplines involved, architectural spaces and components, structural engineering components and building services components.

3.7 IDS – Information Delivery Specification

Léon van Berlo (guest author), Simon Fischer

IDS is a standard from buildingSMART International for the definition of computer-interpretable model exchange requirements. IDS is a relatively young standard and complementary to MVD. While MVD deals with fundamental issues such as the correct representation of the class hierarchy and 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 information requirements. 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 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.

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. Typically, EIR define information requirements based on IFC classes and predefined types. In contrast, IDS can define information requirements depending on attributes, properties, quantities, classification codes, materials, and relations. This kind of selection is sometimes called filtering, but formally called applicability in IDS. 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.

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

Firstly, 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 also 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. This space example is used later to show different ways to visualise IDS.

Secondly, a specification of certain properties for walls using two different specific applicabilities is shown: »*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).*« This 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 considering data from the bSDD and the UCM. The client then exports the information requirements in IDS and sends them to the contractor (appointed party). The contractor uses IDS as a configuration file for both the BIM authoring software and the BIM checking software. This enables the BIM authoring software to create the required properties on an object-specific basis automatically. In the BIM checking software, the configuration file enables automatic filling of checking rules. The checked IFC file is finally sent to the client, who also uses the IDS file to configure their checking software. In the same way, any stakeholder in the project can define their information requirements in a computer-interpretable way. By this, IDS couples the information requirements of the appointing party with the BIM model and enables an automated check of the defined information structure.

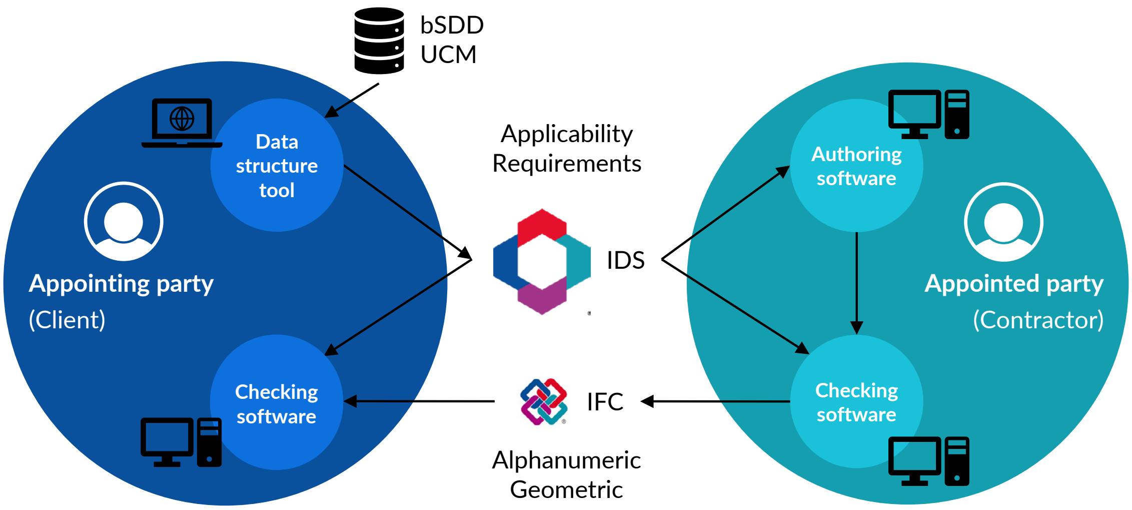


Fig. 3.53: IDS workflow

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 and attributes must and may be included in an IDS file. The following description of the IDS data structure including the facet parameters refers to the IDS version 0.9.6 (status as of January 2024).

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
<?xml version="1.0" encoding="UTF-8"?>
<ids xmlns="http://standards.buildingsmart.org/IDS" xmlns:xs="http://www
    .w3.org/2001/XMLSchema" xmlns:xsi="http://www.w3.org/2001/XMLSchema-
    instance" xsi:schemaLocation="http://standards.buildingsmart.org/IDS
     http://standards.buildingsmart.org/IDS/0.9.6/ids.xsd">
  <info>
    <title>IDS for BIMcert</title>
    <copyright>Simon Fischer</copyright>
    <description>Created to describe IDS for BIMcert</description>
    <date>2023-12-06</date>
  </info>
```

The general metadata is followed by the actual content of an IDS file: a list of *Specifications*. *Specifications* describe information requirements for elements in IFC. They are structured in such a way that they can be easily understood by humans and are also machine-readable. A *Specification* consists of three parts: *Metadata*, *Applicability*, and *Requirements*.

The **Metadata** is included as 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 individual definition of requirements. Through this functionality, IDS can provide advanced definitions of requirements.

Besides the combination of *Facets*, the possibilities within the *Facets* include new features. IDS allows users to require properties to be shared with a certain kind of data type. There are extensive ways 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 specific minimum, maximum, or range. Even pattern matching is an option available in IDS. 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. Restrictions on specifications are another example of an advanced feature. The *minOccurs* and *maxOccurs* attributes in XML allow users to define a minimum, maximum, range, or exact number of objects that must be present in the BIM dataset. IDS uses the XSD restrictions for this to improve the reliability of the implementation. Details on the different *Facet Parameters* follow in a later section. All technical information about IDS can be found on GitHub (see QR code), where code development, documentation, and examples are kept.

In the following, the example of information requirements for walls from the introduction is shown in both a normal text in tabular form (see Fig. 3.54) and IDS (see code on the following page). 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	
...	...	

Fig. 3.54: Information requirements for objects of the class IfcWall

3.7.2 Relation between IDS and IFC

Although IDS can be used to request any kind 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 wall requirement example (in the line *specification*), this specification states that this requirement is made for IFC4. The *Applicability* of this IDS also requires IfcWall. 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.

```
  <specifications>
    <specification name="IfcWall General" ifcVersion="IFC4">
      <applicability>
        <entity>
          <name>
            <simpleValue>IFCWALL</simpleValue>
          </name>
        </entity>
      </applicability>
      <requirements>
        <property datatype="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 datatype="IfcBoolean">
          <propertySet>
            <simpleValue>Pset_WallCommon</simpleValue>
          </propertySet>
          <name>
            <simpleValue>LoadBearing</simpleValue>
          </name>
          <value>
            <simpleValue>true</simpleValue>
          </value>
        </property>
      </applicability>
      <requirements>
        <property datatype="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>
```

3.7.3 Relation to the bSDD

When a user receives an IDS from a client, they can check their own data against the requirements defined in 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 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 which can be specified within the IDS. The bSDD hosts detailed, standardised information about definitions, units, relations to other objects, etc. It does this for classes (classifications) and properties (including attributes and quantities) for both international and national-specific standards. The options for defining restrictions on values in IDS are the same as the ones supported by bSDD. This allows a seamless interaction between IDS and bSDD. Adding the URI to a property or classification (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 Section 3.8.

3.7.4 Facet parameters

This section covers the functionality and capabilities of the six Facet Parameters. For *Facets* used in the *Requirements*, as for *Specifications*, the necessity (occurs) can be specified as an attribute. Some *Facets* also offer or require other specific attributes. The following description contains sample code for each *Facet*. All the sample codes can be included in the *Applicability* and *Requirements* of a *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 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 (not-empty) value. The following code snippet illustrates the use of the *Attribute Facet* to define the name of an element to be Entry.

```
<attribute>
  <name>
    <simpleValue>Name</simpleValue>
  </name>
  <value>
    <simpleValue>Entry</simpleValue>
  </value>
</attribute>
```

Classification Facet

If other classification systems are used in addition to the classes of the IFC scheme, these can be considered with the *Classification Facet*. Lots of such external classification systems like Uniclass2015, CCI Construction or national systems are hosted in the bSDD. 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 attribute of the *Classification Element* to link to further information. In this example, the system CCI Construction with the reference code Window is required. For additional information the URI of the classification (from the bSDD) is provided. If this code snippet is used in the *Applicability* of a *Specification* and combined with *Property Facets* in the *Requirements*, the property assignment to the class defined in the bSDD can be reconstructed.

```
<classification uri="https://identifier.buildingsmart.org/uri/molio/
    cciconstruction/1.0/class/L-QQA">
  <system>
    <simpleValue>CCI Construction</simpleValue>
  </system>
  <value>
    <simpleValue>Window</simpleValue>
  </value>
</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 datatype 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 must be specified as an attribute of the *Property Element*, not as an individual XML element like the others. A URI can also be added as an 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 datatype="IfcBoolean">
  <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 attribute of the *Material Element* to link to additional information about the material.

```
<material>
  <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 attribute of the *PartOf element*, not as an individual XML element like the others. The following code snippet shows the 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">
  <entity>
    <name>
      <simpleValue>IFCBUILDINGSTOREY</simpleValue>
    </name>
  </entity>
</partOf>
```

3.7.5 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 texts 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 for 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 must 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 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.

3.7.6 Scope and usage 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. A list of products operating with IDS can be found at the buildingSMART software implementation list (see QR code and filter for IDS). 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.

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. 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 checking software 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.

3.7.7 Relation to other initiatives

There are many ways to define information requirements. Excel seems to be the most popular but has limitations. Other initiatives are the Product Data Templates (PDT), Level of Information Need (LOIN), *Exchange Information Requirements EIR*, *BIM Execution Plans*, the »exchanges« part of mvdXML, SHACL in the linked data domains, and more. All these initiatives have advantages and limitations. Depending on the use case, other standards or initiatives might be a better choice. Tomczak et al. created a comparision (see QR code and table in Fig. 3.55).

◌ – No
◑ – Partial
● – Yes
* – under development
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	Standardised	Applicability	Fields					Value constraints				Content			Geom.		Metadata		
			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	◌	●	●	●	●	◑	●	●	●	●	●	◑	◑	●	●	◌	◑	◑	◌

Fig. 3.55: Different ways to define information requirements

For most use cases in openBIM the IDS is the recommended solution to define 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 (see also Section 3.4).

3.7.8 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 the code on the following page.

A different way to visualise this XML is shown in Fig. 3.56. Here you 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 IDS in a human- readable way. In such a viewer our example looks like Fig. 3.57. As you can see, there are many different ways to visualise the information in an IDS file.

```xml
<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 datatype="IfcReal" uri="https://identifier.
            buildingsmart.org/uri/buildingsmart/ifc/4.3/prop/
            GrossFloorArea">
          <ids:propertySet>
            <ids:simpleValue>BaseQuantities</ids:simpleValue>
          </ids:propertySet>
          <ids:name>
            <ids:simpleValue>GrossFloorArea</ids:simpleValue>
          </ids:name>
        </ids:property>
        <ids:property datatype="IfcReal" uri="https://identifier.
            buildingsmart.org/uri/buildingsmart/ifc/4.3/prop/
            NetFloorArea">
          <ids:propertySet>
            <ids:simpleValue>BaseQuantities</ids:simpleValue>
          </ids:propertySet>
          <ids:name>
            <ids:simpleValue>NetFloorArea</ids:simpleValue>
          </ids:name>
        </ids:property>
        <ids:property datatype="IfcReal" uri="https://identifier.
            buildingsmart.org/uri/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>
```

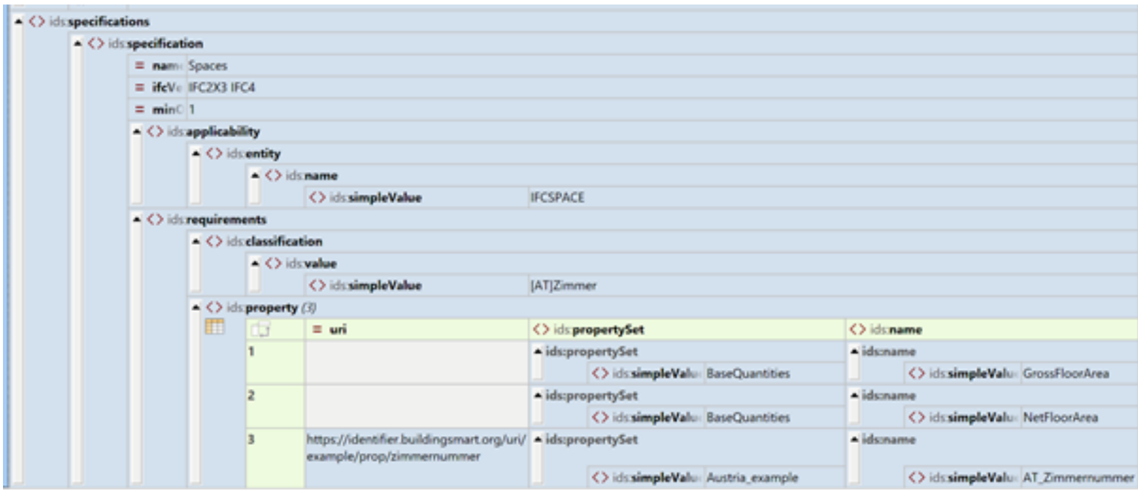


Fig. 3.56: XML visualised as a table

Fig. 3.57: IDS in a viewer

3.8 bSDD – buildingSMART solution for data dictionaries

Artur Tomczak, Jan Morten Loës (guest authors), Simon Fischer

Although the IFC standard contains over a thousand terms and twice as many properties, it mainly addresses the general, universal definitions. The IFC, as the name suggests, consists of foundation classes. These are the foundations upon which additional content can be added, such as technical terms, material names or supplementary properties to describe the data. The need to extend IFC may arise, for example, if we want to comply with local building regulations that require certain classification codes. We may need to provide specific properties for sustainability analysis or map as-built data to asset management systems. IFC allows for referencing classifications and adding custom properties, but this is a manual and error-prone process. The freedom to define new names can lead to different names being used for the same concepts, or the same names having different meanings.

How do we manage the naming convention (syntax) and meaning (semantics) of all the new terms we add? We can find help in so-called *data dictionaries*. In simple terms, data dictionaries are sets of standardised terms and definitions that can be used to create content. This allows others to better understand and interpret the meaning of the data. The bSDD is a free service from buildingSMART International for sharing and accessing such data dictionaries. Anyone can browse its contents and find already registered concepts that can be used to define data. This way, instead of coining new terms, we can reuse the same vocabulary and share the exact same meaning. Each resource in the bSDD has its own unique identifier (URI, *Uniform Resource Identifier*), which also acts as a link to the website with definitions and related information. This ensures that everyone is referring to the same concept, understands its meaning and provides a way for those viewing the BIM data to interpret it. Through relations between concepts, such as hierarchy and composition, data dictionaries can define a complete data structure. Showing the similarity between existing dictionaries can facilitate data exchange in an international construction context and help reduce misunderstandings.

The bSDD aims to serve as a centralised reference library, distributing data dictionaries from different sources and making them available to all user groups. This leads to:

- Consistent and transparent interpretation of data, avoiding uncertainty and communication issues,
- enabling automated processing based on standardised data, and
- enabling comparison and learning, discovering patterns, improving workflows, and sharing knowledge.

In parallel, the bSDD project becomes the shared knowledge graph of relations between classification systems, serving as the basis for unifying the terms and properties and sharing meaning with both humans and machine algorithms.

The bSDD is based on the principles defined in international standards: ISO12006-3 – the framework for object-oriented information, ISO23386 – the methodology for describing, creating, and maintaining properties in interconnected data dictionaries, and ISO23387 on data templates. This standardised organisation of data dictionaries enables users to exchange data based on a common structure, reuse existing content, map content to other dictionaries, and show the relation between different classifications or terms.

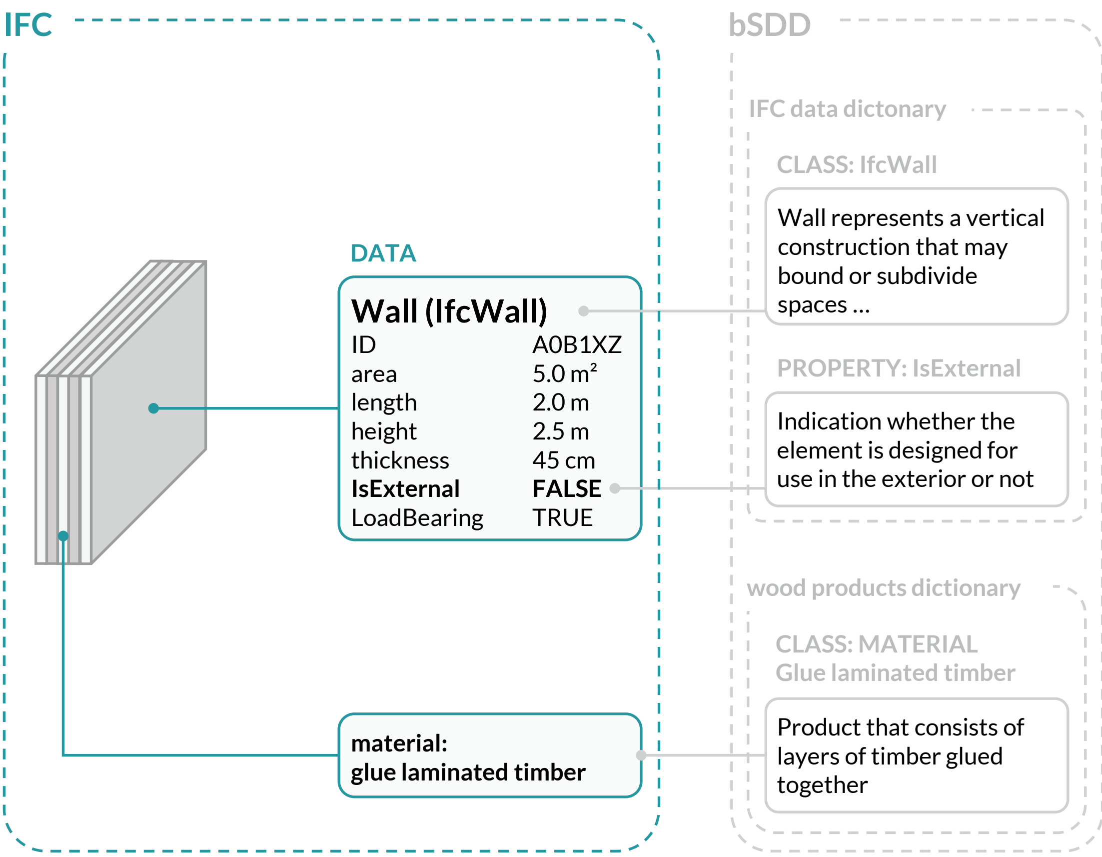


Fig. 3.58: Example wall with terms from bSDD and their definitions

3.8.1 User groups and use cases

The primary purpose of the bSDD is to assign classes to objects, along with common properties and materials. These properties can also be restricted to certain values, e.g. the value of length should be a non-negative number. However, the bSDD can provide many more services and functions for different use cases, depending on the user group.

Data Dictionaries publishers – *people who define terms and want to share them with others, potentially also map to existing content* (organisations, specialist associations, standardisation bodies, private companies, manufacturers, etc.):

- **A common framework for data dictionaries**: bSDD provides a common platform and framework for hosting data dictionaries, also for those who cannot afford to operate a proper server for their data. bSDD also provides global access and compliance with relevant standards.
- **Software integration**: bSDD provides access to many software integrations and common API, allowing it to be integrated into various workflows.
- **Interconnected dictionaries**: data can be integrated into an ever-growing network of data dictionaries by mapping to existing content and uncovering relations.

Data creators – *people who create project and product data (e.g. BIM models) or other relevant content* (designers, asset managers, manufacturers):

- **Data enrichment**: IFC models or other relevant BIM data can be enriched by classifying objects according to a desired standard or (even a private) naming by adding classes, properties, or common material definitions.
- **Data integration**: bSDD provides a source for understanding and creating data by providing lists of terms and values in a standardised way that can be accessed and processed by machines and humans alike, avoiding misunderstandings and eliminating the error-prone manual process of copying data or the production of duplicates and redundancies.

Quality controllers – *people who ensure that the BIM data being delivered is of the right quality and meets the required standards. This also applies to institutions that receive BIM datasets as the basis for processes such as building permits or green certification, as they need to ensure that the dataset meets their requirement* (BIM coordinators and managers, institutions):

- **Data consistency**: The use of bSDD can prevent errors, interruptions, and failures by providing users with lists of possible names and values and thus eliminating misspellings as a source of error
- **Compliance checking**: bSDD can provide terms when creating IDS files for compliance checking software. In this way, a classified model or a model claiming to be created according to a certain standard can be checked to ensure data quality or to verify compliance with the respective dictionaries for the correct use of entities, properties, values, and units.

Data receivers – *people who seek to better understand the content they need to interpret* (operators, clients, designers, contractors):

- **Interpretation**: Classes and properties are no longer just names but can be easily identified and provided with metadata such as the definition, authors, or intended use. This enables a better understanding of the content.
- **Analysis and simulation**: With standardised data, any class, property, or material can be shared and used in common analysis and simulation processes. For example, a product optimisation analysis could be performed to exchange and test different material definitions to determine the most suitable product in terms of environmental impact, energy consumption or cost by simply classifying a model or model components differently.
- **Translation**: bSDD can also store translations, providing users with names in their native language while preserving the machine codes.
- **Data mapping**: In bSDD, any part of a dictionary can be related to other existing dictionaries, thus providing insight into connections or similarities to other definitions, such as international codes or material definitions. This also provides the ability to find equivalents or false friends, unleashing the power of the globally linked knowledge and ensuring data consistency while reducing redundancies.

Software developers – *people who need their software to use and interpret data, combine, and connect different systems, and ensure data consistency and performance* (data engineers, system architects, BIM software specialists):

- **Single source integration**: bSDD can serve as a single source of data definition as it contains a variety of interconnected dictionaries and definitions that can all be derived by connecting to a single, standardised source through common interfaces.

- **Automation**: bSDD enables the automation of processes thanks to standardised terms.

Other user groups – *people or systems that strive for knowledge or interpret relations to uncover new insights* (analysts, researchers, AI):
Researchers can discover how information is structured in other regions or contexts. AI or machine learning algorithms can uncover patterns or insights into how data is connected or used and provide new solutions or reduce redundancy.

The list of use cases for the bSDD is not limited to the above. As a platform of standardised, interconnected data dictionaries, it can become a powerful and central tool for the entire construction industry and beyond, providing the foundation for data integrity and consistency.

3.8.2 Practical usage

As the bSDD is primarily a reference library of standardised terms, it is possible to manually copy and paste definitions from the bSDD into documents or datasets. The content can be browsed on the bSDD search page (see QR code). A much simpler approach is to use software solutions integrated with bSDD, as these provide a convenient user interface for accessing and referencing the bSDD content. A digital tool also reduces the risk of human error when copying or typing in names. The latest list of tools claiming to support specific *openBIM* solutions, including bSDD, can be found on a buildingSMART website (see QR code). Fig. 3.59 shows an example of software implementations using content from bSDD.

Such software integrations are made possible thanks to the bSDD API (application programming interface). For those familiar with programming, bSDD offers its content through the REST API (JSON and RDF) and the GraphQL query language. More information, instructions, and interactive documentation can all be found on the bSDD website (see QR code).

3.8.3 Content of bSDD

The content of the bSDD consists of individual data dictionaries. Each data dictionary may contain classes, properties, and relations between them or to other dictionaries. Due to the rather universal definition of a data dictionary, it can correspond to a classification system, taxonomy, meronomy, ontology, nomenclature, data structure, data template, material library, thesaurus, metadata, etc.

In addition to the *Dictionary*, *Class*, and *Property* concepts already mentioned, the bSDD also allows the definition of *AllowedValue*, *ClassProperty*, *ClassRelation*, and *Property-Relation*. Each concept is associated with a parent dictionary, has its own identifier and metadata. Full documentation of all the information that can be included in the bSDD can be found on GitHub (see QR code).

Dictionaries are the highest level of the bSDD data model. A dictionary is a container consisting of metadata and two lists: classes and properties.

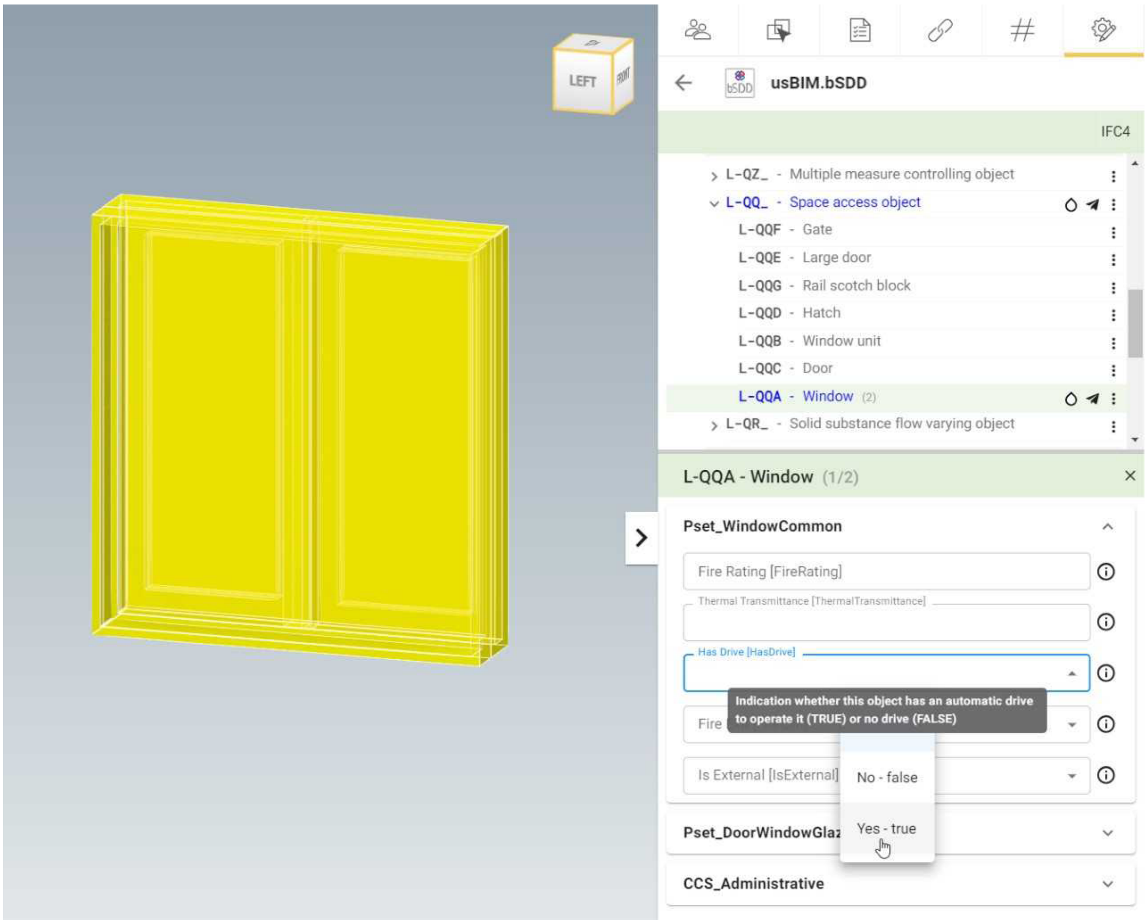


Fig. 3.59: User interface for classifying IFC models with the bSDD conent (ACCA usBIM)

Classes define objects with the same characteristics. The bSDD distinguishes between four types of classes. The first and most common type, Class, describes real things like a door or a window. *GroupOfProperties* organises properties. The *Material* type distinguishes classes that represent physical materials. Thanks to this, software knows how to interpret such classes and make them available to its users. Finally, the *AlternativeUse* type can be used if none of the predefined types fits. This type should be used with care, as most software will not make use of it. Classes can be organised hierarchically in a tree structure by reference to their parent class. Each class can be the *child* of one *parent class* and the *parent* of several *child classes*. However, *child classes* do not inherit information from their *parent class*. For example, properties assigned to the *parent class* are not automatically part of the *child class*.

The **bSDD Properties**, like those in IFC, define alphanumeric information that describes an object. Example properties include »Height« expressed as a numeric value, »Identification« as a string of digits, letters, and other characters, and »Status« as one of a few possible values (enumeration). In addition to their name, identifier, definition and data type, properties in data dictionaries can also be restricted to certain values. Similar to IDS, the bSDD allows you to list allowed values (*AllowedValue*), specify patterns (*regular expressions*) for text values, or define lower and upper limits for numeric values.

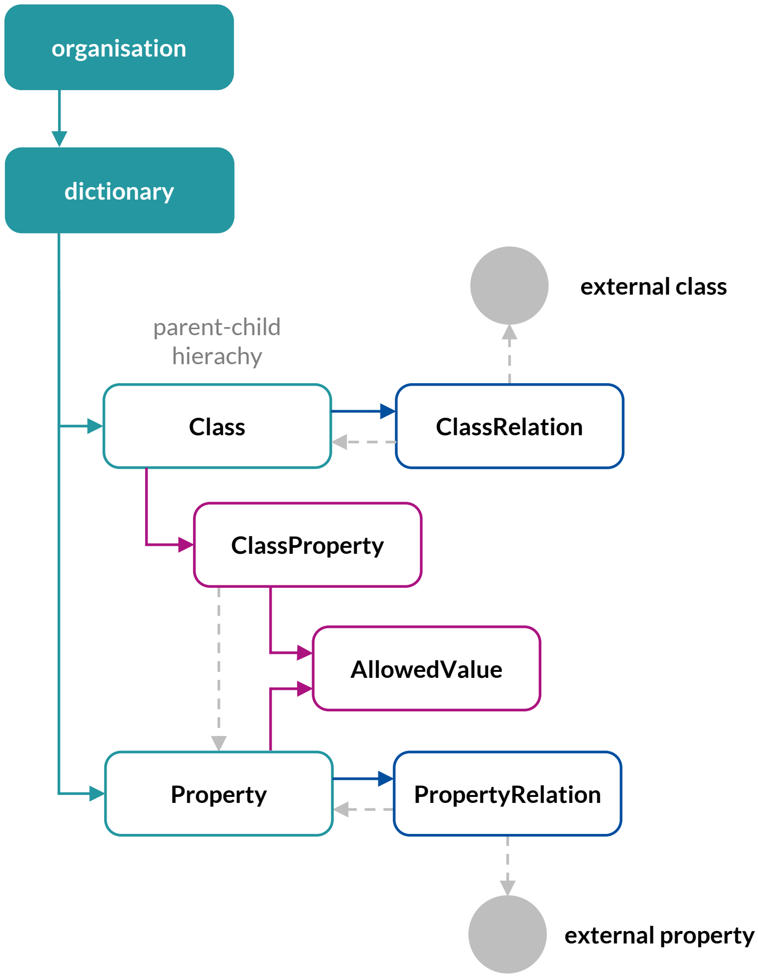


Fig. 3.60: Concept of a bSDD structure

Properties and classes are independent concepts in bSDD that can be combined by using **ClassProperties** It is basically an assignment of properties to a particular class. We say it is an instantiation of a general property for a particular class. Each property can be assigned to several classes. The *ClassProperty* can be used to assign properties from the same dictionary as the class, but also to reuse properties from different existing dictionaries to avoid duplication. By default, all property information is passed to the *ClassProperty*. However, it is possible to override the default values. For example, a general »Temperature« could take any value from -273.15°C up, but when talking about the temperature of water flowing in a system, the range would be between 0-100°C. The data can only be specified at this stage, not completely changed. For example, if the property defines three allowed values, the *ClassProperty* can limit it to one or two for the specific class, but it cannot add a value that is not present in the original property. An important aspect of class properties is the property set. This tells where the property should be located in the IFC model. While a property can be a member of several groups (*GroupOfProperties*), a *ClassProperty* can only be assigned to one property set. Defining a property set at the *ClassProperty* level allows it to be stored in different sets for different classes. For example, the default *FireRating* property is stored in Pset_WallCommon for walls, but in Pset_SlabCommon for slabs.

The last two concepts – **ClassRelation** and **PropertyRelation** – are intended to map concepts and define how they relate to one another. Classes and properties can have relations

- *IsEqualTo* – if two concepts are unequivocal and have exactly the same name, code, definition, description, and same class properties,
- *IsSimilarTo* – if two concepts are almost the same but differ by name, code, definition, description, or set of class properties, and
- *HasReference* – if two concepts are related but other types of relation do not apply (for example, »window« is referencing a wall).

ClassRelations can additionally be *IsChildOf* and *IsParentOf* – defining the hierarchy or specialisation, or *HasPart*, *IsPartOf*, and *HasMaterial* – showing the composition. The relations allow you to find equivalent or similar codes and properties from other dictionaries. For example, you may need to follow different classification systems when designing a road that spans two countries. Thanks to the mapping, both teams can understand the similarities between their datasets and quickly provide others with terms they are familiar with. Because IFC is the base dictionary of the bSDD, it can be linked directly within a class (via the attribute *RelatedIfcEntities*) without using a *ClassRelation*.

Fig. 3.61 shows a real example from the bSDD, containing most of the general concepts explained above. On the left is the *CCI Construction dictionary* and on the right is the representation of the IFC structure as a dictionary in the bSDD. The *CCI Construction dictionary* contains many classes in a parent-child hierarchy and defines one new property. In our example we focus on the class *Window*. It references definitions inside and outside the *CCI Construction dictionary*. A relation to the IfcWindow definition of the IFC dictionary is created via the attribute *RelatedIfcEntities*. ClassProperties are used to include properties from the same dictionary (*CCSTypeID*) as well as the existing IFC dictionary (e.g. *IsExternal*) and to store them in specific property sets. The other concepts, *ClassRelation* and *PropertyRelation*, are not used in this example.

The contents of the bSDD can have one of three possible statuses: *Preview*, *Active*, and *Inactive*. When content is published, it is initially set to *Preview* status. At this point, the author can re-upload and overwrite the data dictionary or even delete it. Only when a content is activated (status changed to *Active*) does it become immutable, i.e. it will remain unchanged in the bSDD for as long as the bSDD exists. This status indicates that it is safe to use the content in projects and contractual agreements. When a new version is added, the owner may decide to deactivate previously active content. *Inactive* content remains accessible and immutable.

3.8.4 Referencing from bSDD to IFC

In the context of an IFC model, the terms from the bSDD are external information that offers the possibility to enrich the existing data. To integrate them, the IFC data structure provides the concept of classification references, which consists mainly of three entities. IfcClassification serves to specify the classification system used or, in the case of bSDD, the dictionary. IfcClassificationReference defines a specific class of the dictionary. Both entities have an attribute to reference the source of the data using a URI where more information about the definitions is provided. Finally, the relation IfcRelAssociatesClassification creates the link between the specified class and the classified objects. This is illustrated in Fig. 3.62, which show the classification of an IfcWindow as a *Window* from the *CCI Construction dictionary* schematically and in the IFC file (STEP Physical File). The last two attributes of IfcRelAssociatesClassification refer to the entity IfcWindow (#886) and the external class *Window* (#916).

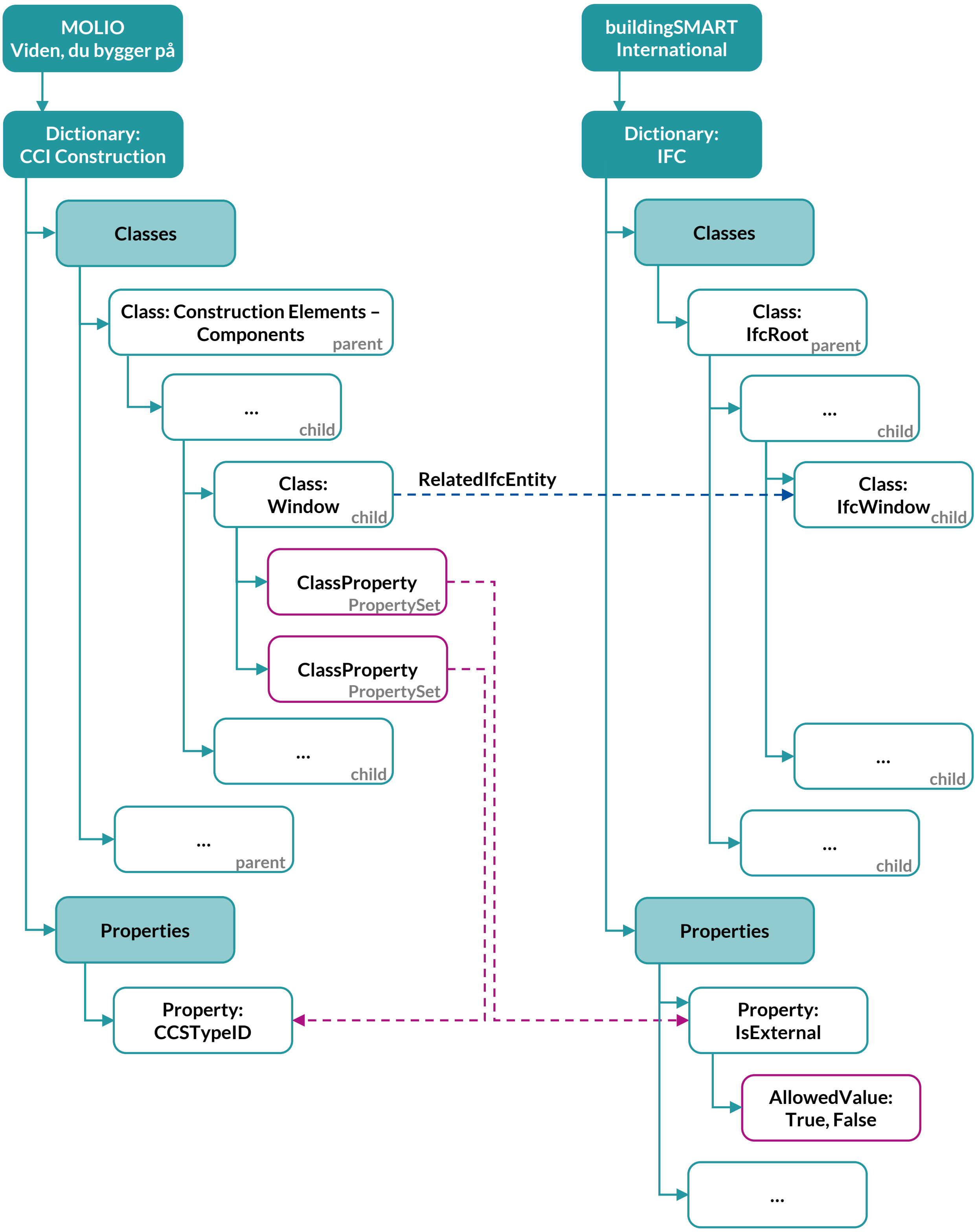
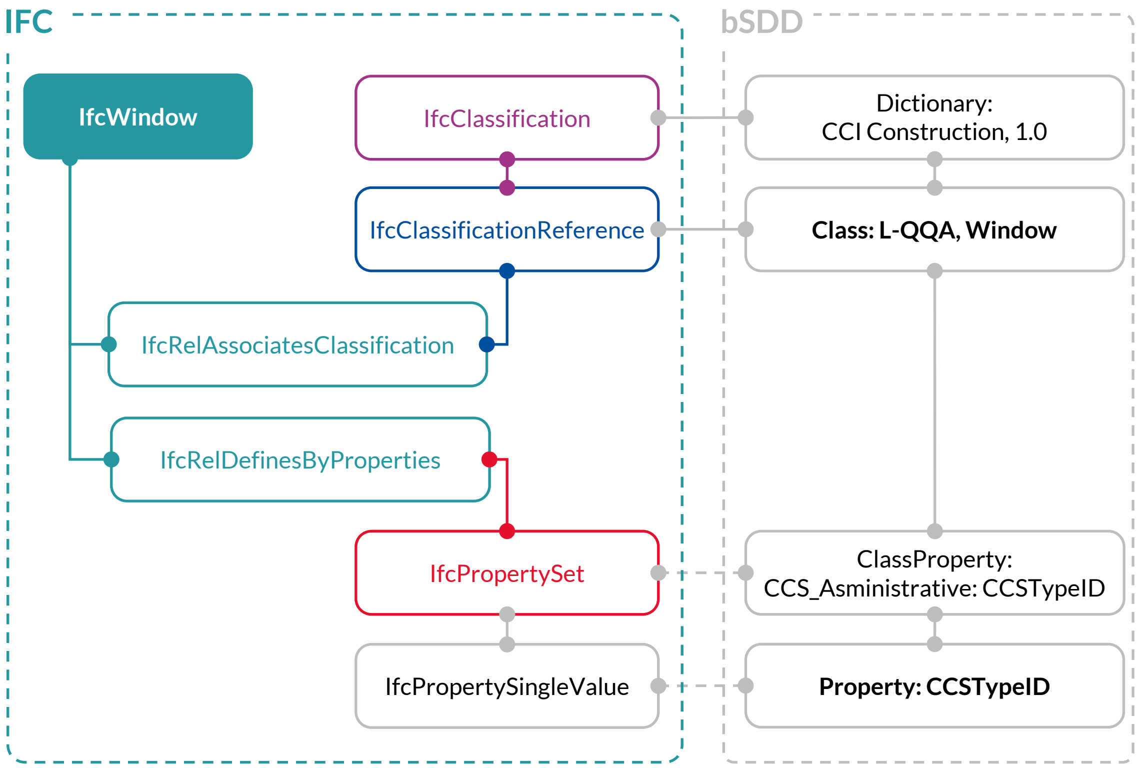


Fig. 3.61: Use of various bSDD concepts to describe the class Window of the CCI Construction Dictionary

The last six lines in Fig. 3.62 show the association of properties defined in the bSDD class. Regardless of whether a newly defined or existing property is used in the bSDD, its association with external classifications is not stored. All properties are treated the same in IFC. They are only linked to their respective objects, as indicated by the second last attribute of IfcRelDefinesByProperties. While the information that these properties have been assigned by an external classification is not explicitly presented, the focus remains on the seamless association of properties with their designated objects. Note that the integration differs slightly between IFC versions. Full documentation is available on Github: »bSDD-IFC documentation« page.



Declaration of the IfcWindow object
#886 = **IFCWINDOW**('2s91HGDcf4pvesZmvoXaqK', #12, 'Window-001', $, $, #425, #877, $, 1.5, 9.E-1, .WINDOW., $, $);
...
Used data dictionary
#915 = **IFCCLASSIFICATION**('molio', '1.0', '2023-01-01', 'CCI Construction', $, 'https://identifier.buildingsmart.org/uri/molio/cciconstruction/1.0', $);
Used class of the data dictionary
#916 = **IFCCLASSIFICATIONREFERENCE**('https://identifier.buildingsmart.org/uri/molio/cciconstruction/1.0/class/L-QQA', 'L-QQA', 'Fenster', #915, $, $);
Relation between the used class and the classified object
#917 = **IFCRELASSOCIATESCLASSIFICATION**('3a3lQFAlrRceFf3oC7QLjE', #12, 'Objekt zur Klassifizierung', $, (#886), #916);
...
Usage of a new property in an individual property set
#960 = **IFCRELDEFINESBYPROPERTIES**('24Cy7uzn5Ju8KKmcMZccmW', #12, 'Objekt zu Eigenschaften', $, (#886), #961);
#961 = **IFCPROPERTYSET**('14EphN_ZzRXujTCUh2zeg4', #12, 'CCS_Administrative', $, (#962));
#962 = **IFCPROPERTYSINGLEVALUE**('CCSTypeID', $, IFCTEXT('ExamplePropertyValue'), $);
...
Usage of an existing property of another data dictionary (e.g. IFC4)
#966 = **IFCRELDEFINESBYPROPERTIES**('2JygXoqUnVP8iD1jXuVBaJ', #12, 'Object to Properties', $, (#886), #967);
#967 = **IFCPROPERTYSET**('0_QJCthkXHV9_iyFnB1i_V', #12, 'Pset_WindowCommon', $, (#968));
#968 = **IFCPROPERTYSINGLEVALUE**('IsExternal', $, IFCBOOLEAN(.T.), $);

Fig. 3.62: Representation of external classes and properties in STEP Physical File format (IFC4)

3.8.5 Referencing to bSDD in IDS

The bSDD provides terminology that can be used in IDS specifications. The IDS author can look up standardised terms and require their presence in IFC data. This applies to all IDS components, such as properties, classifications, and materials. Some software products offer the functionality to browse the bSDD database when creating an IDS. When referring to standard names from bSDD, their identifier in the form of a URI can be stored in the special IDS attribute »URI«. This can be used to obtain more information about a term, such as its meaning, context, or how a property value should be measured.

Fig. 3.63: User interface of Plannerly allows to browse the bSDD content when creating IDS

3.8.6 Publishing content in bSDD

The bSDD can be used as a framework for several interconnected data dictionaries. While the content is published in a common framework and structured according to a common standard, its origin can be diverse. Any organisation can create its own data dictionary and publish it in the bSDD, as long as it meets the objectives and rules of the service. The content should be related to the construction industry, should not violate license agreements, or promote commercial products, and should allow reuse by others. Authors should avoid uploading derivative versions of existing classifications but should instead complement them where necessary or propose improvements.

The process of creating and maintaining data dictionaries can vary greatly, from complex management platforms following ISO 12006-3 and ISO 23386 standard procedures to simple spreadsheet lists. The bSDD platform allows properly structured JSON files to be used as input, as long as they conform to the bSDD data structure. The latest template file is available on GitHub. The documentation of the bSDD data model provides guidance and explains which attributes are required and what values are expected. Such a JSON file can be uploaded manually via the bSDD management portal (see QR code) or by third party software via an API (see the list of software tools offering bSDD content creation and maintenance on the buildingSMART website). In addition to dedicated third-party tools and textual JSON input options, bSDD content can also be prepared in a spreadsheet. The bSDD repository contains both the Excel template file and the Python script that automates the conversion to the desired JSON form. The bSDD platform allows content to be uploaded and accessed free of charge as it is intended to be publicly accessible. The bSDD also offers a paid service for hosting private data dictionaries with restricted access. This feature provides the benefits of the bSDD, but for company or project specific data that is not intended to be shared publicly.

3.9 UCM – buildingSMART Use Case Management Service

Thomas Glättli (guest author)

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. Fig. 3.64 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.

Fig. 3.64: Use cases address the entire value chain

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 domains (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).

Fig. 3.65 shows the »Model-based layout of reinforcement« use case with the property sets defined in the exchange requirements and the idsXML export

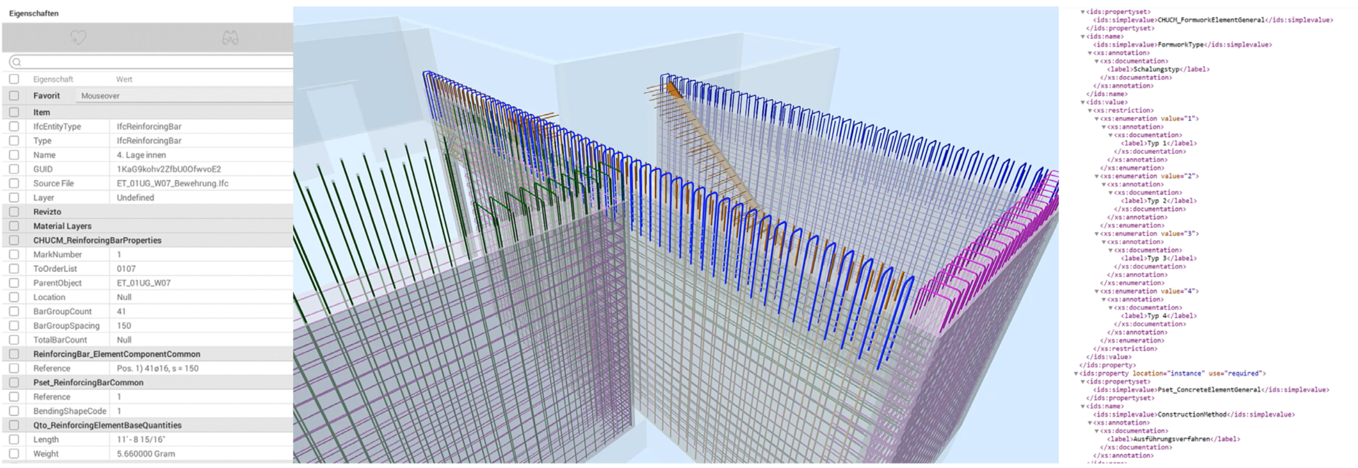


Fig. 3.65: Use Case »Model-based layout of reinforcement«

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 Fig. 3.66). 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 infor-

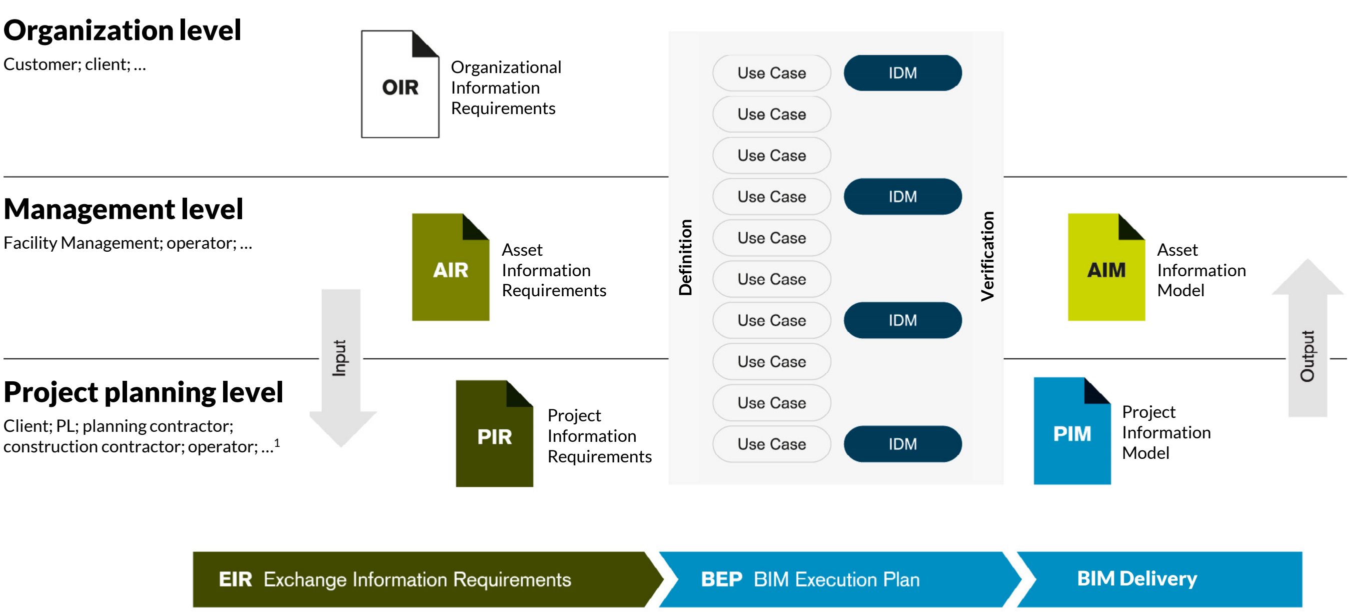


Fig. 3.66: BIM process model from Bauen digital Schweiz / buildingSMART Switzerland

mation 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.

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.

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 and defines the project organisation together with the buildingSMART chapter.
  - buildingSMART creates the project structures in the UCM service.
- kick off meeting
  - The project manager 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
  - Exchange requirements are structured and detailed in tabular form.
- IFC mapping / IDS
  - Exchange requirements are linked to IFC. The different IFC releases must be taken into account.
  - 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.

Fig. 3.67: Use Case »Fall protection (Absturzsicherung)« – side protection on a construction site

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

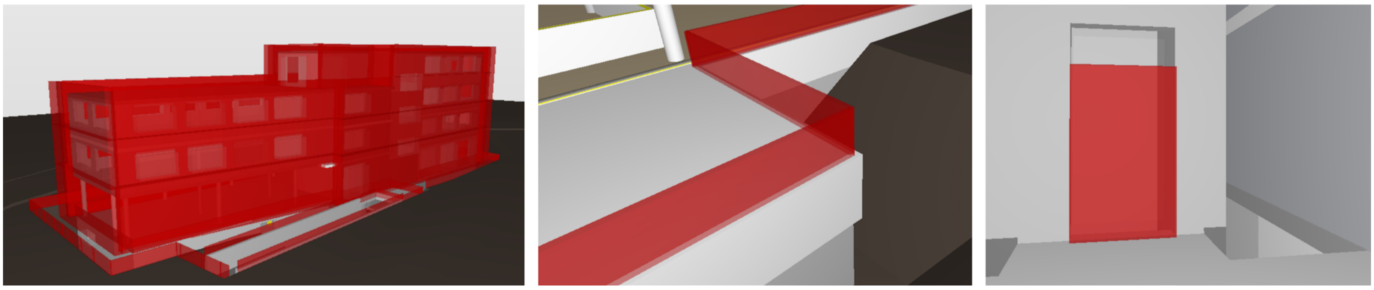


Fig. 3.68: Use Case »Fall protection (Absturzsicherung)« – models

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 during the phases of a building (EN 16310): initiative, initiation, design, procurement, and construction. A comparison with national phases is provided in Fig. 4.3 and Fig. 4.4. It explains the functional steps and activities required for *openBIM* project implementation. Chapter 1, Chapter 2, and Chapter 3 are assumed as prior knowledge. The procedures presented should always consider the BIM implementation documents *Client's EIR* and BEP as well as national standardised service specifications (for the BIM organisational structure).

General information on Exchange Information Requirements EIR

In accordance with ISO 19650, the *Exchange Information Requirements EIR* are used for the definition of requirements for the information exchange between the *appointing party* and the *appointed party*. There are different *appointing parties* at different levels in a project, e.g. the *client*, the *lead appointing party*, *other appointing parties*. The *lead appointing party* has to fulfil the *EIR* of the *client* and can subdivide these EIR and pass it on to sub-partners. The *(lead) appointing parties* can also augment the received EIR with their own EIR.

At the top level is the *client's exchange information requirements* for the entire project. In the past, this EIR document was called »*Employer Information Requirements*«. This term is still in use in Austria and Germany for the (in German: »*Auftraggeber-Informationsanforderungen AIA*«). In Switzerland, the terms of the ISO 19650 series are used, and the document is referred to as »*Exchange Information Requirements*«.

To avoid confusion between the information exchange requirements (at the different levels), the term »*Client's* **EIR**« is used in the BIMcert Handbook when referring to the EIR document at the top level (of the *client*).

As an example, the regulations provided free of charge by bSAT (EIR, BEP; EIR & BEP of the BIO Institute) and the service specifications from bSAT are linked (see QR code).

In Switzerland, a national glossary for digitalisation in the construction and real estate industry is available, which provides a standardised, consolidated terminology for digitalisation in the design, construction, operation, and demolition of buildings. It was created in collaboration between Bauen digital Schweiz / buildingSMART Switzerland, the Swiss Central Office for Construction Rationalisation (CRB), the Swiss Federal Railways (SBB) and the Swiss Society of Engineers and Architects (SIA) and is constantly being updated (see QR code).

bimdeutschland.de provides examples and working aids for EIR and BEP (see QR code, section »Umsetzungsstrategie BIM für Bundesbauten und BIM-Handbuch« on the QR code website).

Overview of the BIM organisational structure (subset of project organisational structure)
Section 2.5 provided an introductory description of the *BIM roles* in the *openBIM* process. This section places the roles into the context of the BIM organisational structure. The detailed description of BIM project execution is provided in the following sections. Fig. 4.1 and Fig. 4.2 provide an overview of the basic BIM organisational structure in the design and construction phases, respectively. However, an individual organisational structure may need to be developed for each project according to the project-related framework.

The *BIM function* (*role*, organisational unit) *BIM Management* represents the client's interests. It consists of the two roles: *BIM Management (client)* and *BIM Management (control)*.

BIM Management (client) takes over the implementation of the non-delegable tasks of the client and is involved in the project at an early stage. It is responsible for specifying the framework conditions of the project, defining the *service specifications* used by the respective actors, and implementing the client's requirements for the data structure used in the project. It is in charge for preparing the *Client's EIR*, which maps the client's information needs. This should also define and include the information requirements for operation (AIR). As part of the *openBIM* process, the specifications for the data to be supplied and the formats for data exchanges will be defined based on the buildingSMART standards. The topic of standardisation is described in Section 2.2 and Section 3.1.

BIM Management (control) is responsible for the operational implementation of the BIM project within the framework of the specifications defined by *BIM Management (client)*. It concretises the framework specifications of the *Client's EIR* and, on this basis, develops the *pre-BEP* which contains the minimum requirements and the structure. The project team develops then the project-related *BEP*.

From this, the contractor (project team) develops a BEP that is updated as the project progresses. *BIM Overall Coordination* is the responsible *BIM role* for the BEP. This BEP and its updates are approved by the *BIM Management (control)*. This forms the basis for BIM-based collaboration during the project. If the contractors have their own contractors, they must also pass on the requirements (sub-EIR). The *Client's EIR* is part of the contract between the client and the project team, as it contains fixed requirements – the BEP, on the other hand, is a »living document« with the character of a guideline.

BIM Overall Coordination coordinates and verifies the interdisciplinary BIM content of the project team. This role is the primary point of contact for the digital design to the *BIM Management (control)*. *BIM Overall Coordination* is responsible for the coordination model and monitors the implementation of the tasks of the respective *BIM Domain Coordination*. The *BIM Domain Coordination* verifies the domain-specific BIM content of the individual disciplines/domains.

BIM Management includes the tasks (roles) of *BIM Management (client)* and *BIM Management (control)*. In Germany and Switzerland, this is always summarised under the role of *BIM Management*.
In Austria, the responsibilities can be divided into separate organisational units for *BIM Management (client)* and *BIM Management (control)*. *BIM Management* is used when the tasks of *BIM Management (client)* + *BIM Management (control)* are carried out by the same organisational unit – this is usually the case for clients with in-house BIM project

competences who cover these tasks completely independently, or for clients who have to outsource these tasks completely because they do not have the resources to handle *BIM Management (client)* independently. *BIM Management* should be seen as an integral part of project management.
When the terms *BIM Management (client)* and *BIM Management (control)* are mentioned in the *BIMcert handbook*, this always refers to the area of responsibility – regardless of whether this is carried out in separate organisational units or in *BIM Management*.

BIM Management is often also referred to as Information Management. Information Management consists of project members who record the EIR and define BIM objectives and applications as part of the project management process. They are responsible for the organisational tasks of defining, implementing, maintaining, and documenting BIM processes throughout the lifecycle of a building. They are also the point of contact for the client and responsible for the CDE. Information managers come from different backgrounds at different stages of the lifecycle. When there is a change in Information Management, it is the responsibility of the new Information Management team to check the quality, currency, and completeness of the BIM model. Information Management coordinates tasks and processes with stakeholders, particularly at the operational level, through information coordination (based on VDI 2552 Part 7).

Example of BIM project development in building construction
Fig. 4.1 shows the project team during the design phase. The *Surveying* team begins with an as-built survey and creates the terrain (surrounding) and as-built model (this model can also be created by the *Design Contractor*). Once this model has been checked, it is made available as a design basis for architecture, structural engineering, building services, and building physics. The various *Design Contractor*s (different domains) create their own domain models under the direction of the respective *BIM Domain Coordination*. *BIM Overall Coordination* merges these different domain models into a coordination model and checks them against each other. Project participants exchange reference models for mutual coordination. In an *openBIM* process, the domain models are exchanged in IFC format. Model-based communication between project participants takes place using BCF comments. The exchange between project participants takes place via a CDE. The model-based collaboration is not limited to the design domains with own domain models; other design participants are also involved in the process. For example, fire protection design is often integrated into the architecture design using BCF comments, or the health and safety plan of the design coordinator is considered in the overall coordination. These non-modelling design disciplines therefore do not create their own domain model but influence the model creation or model coordination with their comments. However, non-modelling design disciplines could later become *BIM Modeller* and then create their own domain models. The coordination model can be used as the basis for tendering, awarding, and contracting construction services. In addition to the modelled elements, the underlying tender model must also consider tender-relevant elements, such as site facilities and required excavation volumes. Any alternative proposals may result in a tender model.

BIM roles have tasks that need to be performed by *people*. However, the *number of roles* is *not the same* as the *number of people*. A good example of this is the fact that in many cases, the person who creates the architecture domain model (*BIM Modeller*) can also take on the role of *BIM Domain Coordination* for the architecture and, if necessary, *BIM Overall Coordination* in smaller projects.

In Austria, the standardised service descriptions for building construction refer to the LB-HB. With ÖNORM A 2063-2, a structure for an element list (elements for tendering, awarding, invoicing) is currently being developed, which will link the model with the standard service descriptions and define standardised material declarations.

In Switzerland, the CRB's eBKP (element-based construction cost plan) is an element-based construction cost plan for model-based cost costing and tendering.

Fig. 4.2 shows the project team during the construction phase. Execution models for architecture, structural engineering, building services, building physics, site facilities, costing and ancillary works, and a health and safety plan are produced as part of the construction phase. The assigned *Surveying* team carries out as-built documentation during construction. On-site surveying is coordinated by the local site supervisor. The resulting point clouds are compared with the domain models. *BIM Overall Coordination* identifies and coordinates any deviations and documents the result in the model. The level of detail of the documentation depends on the relevance of the changes for downstream processes. The result is a complete documentation of the as-built status using the updated domain models. This as-built status is transferred to the asset information model AIM, including the updated domain models and the technical documentation.

This chapter is structured according to the phases (EN 16310): initiative, initiation, design, procurement, and construction. The phase designations vary from country to country. The phases of selected standards are compared in Fig. 4.3 and Fig. 4.4 to ensure that the sections are linked to the national phase designations.

The HOAI (Official Scale of Fees for Services by Architects and Engineers) is currently being revised (2024). This includes adjustments to the topics of design in existing buildings, building information modelling and sustainability.

Fig. 4.5 depicts the BIM organisational structure described above and the models required along the phases. At the beginning of the initiation phase, the foundations required for tendering the design services are established – the BIM organisational structure, the service specification, and the *Client's EIR*. The basis for the *Client's EIR* is provided by the service specifications, which specify the relevant roles and their respective tasks and responsibilities. Therefore, the BIM project organisational structure is usually defined in the *first step*, and the associated service specifications are defined in the *second step*. The latter define the core services and any optional services of the intended roles in the project. This is the basis for the *Client's EIR* which will include requirements for data structure, level of detail, interfaces, labels, data transfer, and collaboration platform. These consider different use cases, in particular operational requirements, and ensure that the information generated during the design and construction phases can be reused. In the next step, the *BIM Management (control)* produces a pre-BEP. This is based on the project-related *Client's EIR* and specifies the exact sequence for implementing the EIR specifications during the project. The initiation phase is completed with the determination of the BEP by *BIM Overall Coordination*, in which the specifications for the model-based project implementation are agreed and evaluated based on the pre-BEP with the help of the design team. The BEP forms the basis for all communication, collaboration, data exchange, and control processes in the design, procurement, and construction phases. The BEP is a »living document« and will be updated throughout all phases. If necessary, the BEP will be adapted as required by the *BIM Overall*

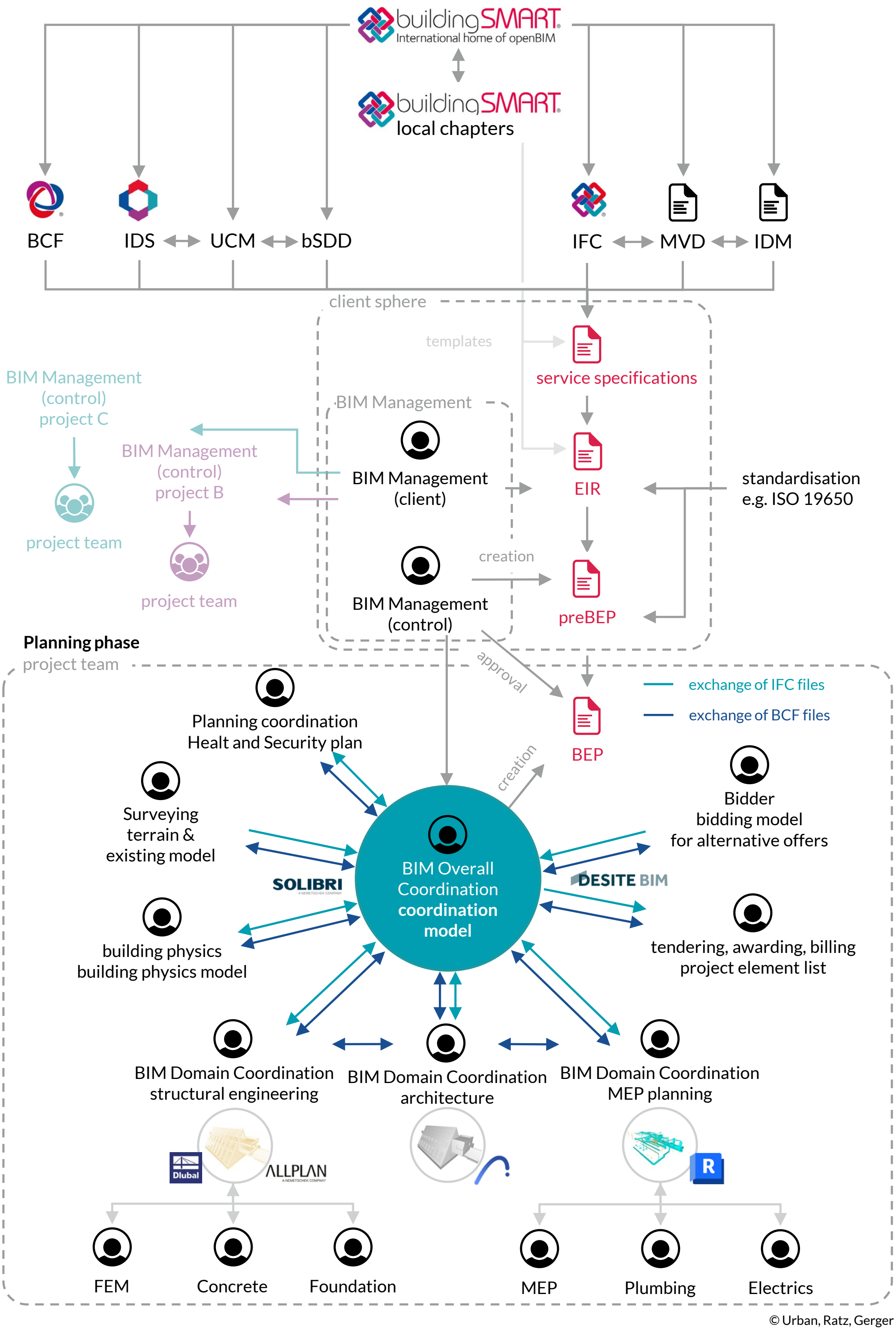


Fig. 4.1: Project team with project participants in the design phase

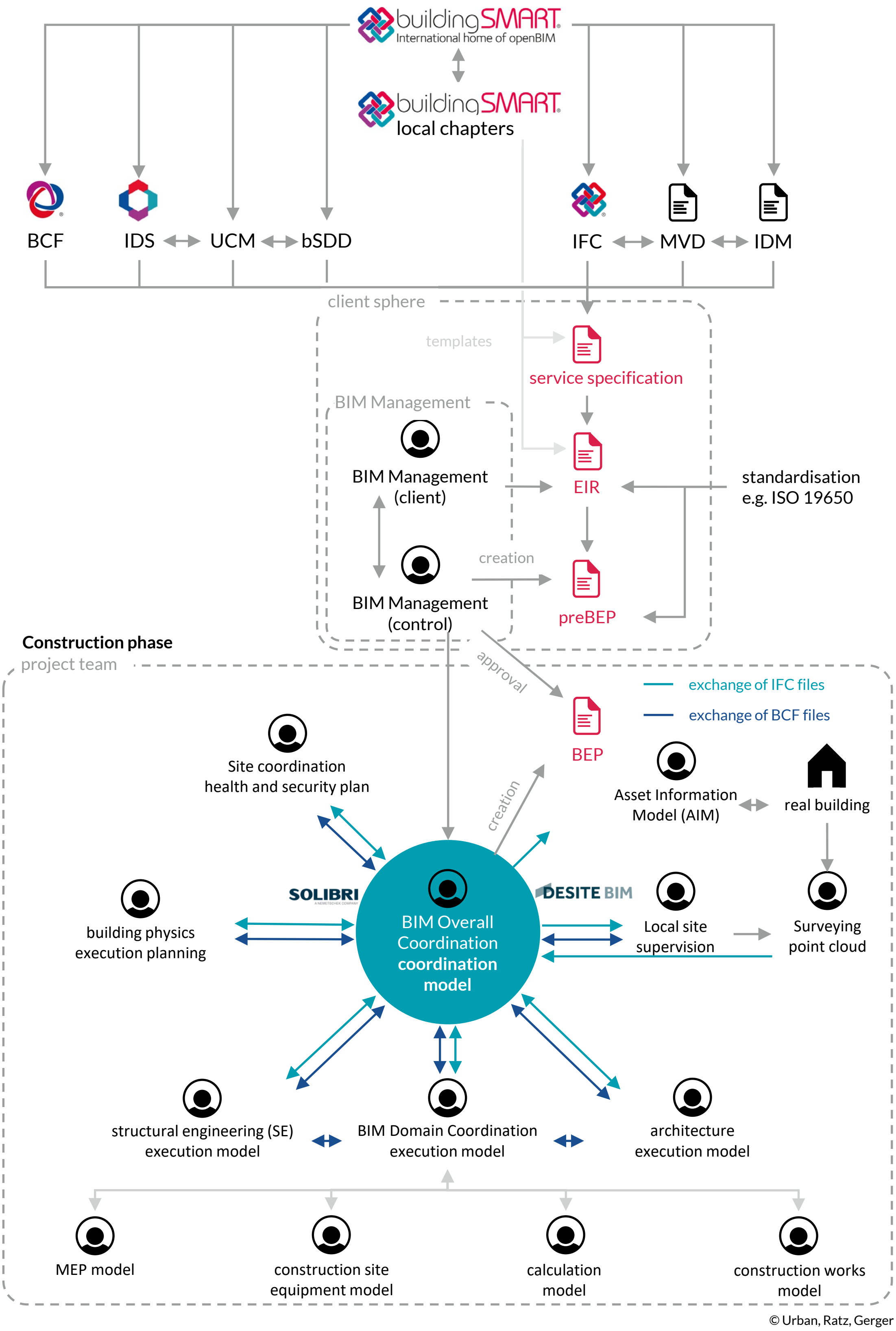


Fig. 4.2: Project team with project participants in the construction phase

ISO 22263:2008		EN 16310:2013		HOAI (Germany)
0. Inception	0.1 Portfolio requirements	**0. Initiative**	0.1 Market study	**LP1 Establishing the basis of the project**
			0.2 Business case	
1. Brief	1.1 Conception of need	**1. Initiation**	1.1 Project initiation	
	1.2 Outline feasibility		1.2 Feasibility study	
	1.3 Substantive feasibility		1.3 Project definition	
2. Design	2.1 Outline conceptual design	**2. Design**	2.1 Conceptual design	**LP2 Preliminary design**
			2.2 Preliminary design and developed design (B&I)	**LP3 Final design**
			2.3 Technical design or FEED	
	2.2 Full conceptual design		2.4 Detailed engineering	**LP4 Building permission design**
				LP5 Execution design
	2.3 Coordination design (and procurement)	**3. Procurement (IF)**	3.1 Procurement	**LP6 Preparation of contracted award**
				LP7 Assisting award process
			3.2 Construction contracting	
3. Production	3.1 Product information	**4. Construction**	4.1 Pre-construction	**LP8 Project supervision**
	3.2 Construction		4.2 Construction	
			4.3 Commissioning	
			4.4 Hand over	
			4.5 Regulatory approval	
4. Maintenance	4.1 Operation & maintenance	**5. Use**	5.1 Operation	**LP9 Project control and documentation**
			5.2 Maintenance	
5. Demolition	5.1 Disposal	**6. End-of-life**	6.1 Revamping	
			6.2 Dismantling	

Fig. 4.3: Comparison of the phase designations in different standards (Source see QR code, adapted)

SIA 112 (Switzerland)		ÖNORM A 6241-2 (Austria)	
1. Strategic planning	1.1 Definition of needs, solution strategies	**0. Project initiative**	0.1 Market study
			0.2 Business case
2. Preliminary studies	2.1 Project definition, feasibility study	**1. Project initiation**	1.1 Project definition
	2.2 Selection procedures		1.2 Feasibility study
			1.3 Project definition
3. Project	3.1 Preliminary project	**2. Design**	2.1 Base model
			2.2 Preliminary design – Coordination model
	3.2 Construction project		2.3 Design – Coordination model
	3.3 Permit-obtaining procedure / submitted project		2.4 Building permission design
			2.5 Execution design
4. Invitation to bid	4.1 Invitation to bid, comparison of quotations, applications für contract awarding		2.6 Tendering
		3. Awarding	3.1 Procurement
5. Implementation	5.1 Construction project	**4. Construction**	4.1 Execution planning and coordinated implementation planning
	5.2 Implementation		4.2 Construction
	5.3 Comimissioning, completion		4.3 Hand over
6. Management	6.1 Operation	**5. Use**	5.1 Operation
	6.2 Surveillance, inspection, service		5.2 Maintenance
	6.3 Maintenance		
		6. End-of-life	6.1 Revamping
			6.2 Dismantling

ISO 22263:2008		ISO 12006-2:2015	STB2014 (Netherlands)
0. Inception	0.1 Portfolio requirements	**1. Inception / procurement**	**1. Initiatief Haalbaarheid**
		2. Feasibility	**2. Projectdefinitie**
1. Brief	1.1 Conception of need	**3. Outline porposals, programme preparation**	**3. Structuurontwerp**
	1.2 Outline feasibility		**4. Voorontwerp**
	1.3 Substantive feasibility		**5. Definitief Ontwerp**
2. Design	2.1 Outline conceptual design	**4. Schema detail / costing**	**6. Technisch Ontwerp**
			7. Prijs- en contractvorming
	2.2 Full conceptual design	**5. Detail design / costing**	**8. Uitvoering – Uitvoeringsgereed Ontwerp**
	2.3 Coordination design (and procurement)	**6. Production information and bills of materials**	**9. Uitvoering - Directievoering**
		7. Tender action	**10. Gebruik/exploitatie**
			11. Beheer
3. Production	3.1 Product information	**8. Construction preparation**	**12. Onderhoud**
	3.2 Construction	**9. Construction operations onsite**	**13. Fabricage**
		10. Completion	**14. Montage**
4. Maintenance	4.1 Operation & maintenace	**11. Feedback**	
5. Demolition	5.1 Disposal		

Fig. 4.4: Comparison of the phase designations in different standards (Source see QR code of Fig. 4.3, adapted)

RIBA plan of work (Royal Institute of British Architects)	CSI / CSC — Omni Class Table 31 - Phases (Canada / USA)
0. Strategic Definition	**31-10 00 00 Inception Phase**
	31-20 00 00 Conceptualization Phase
1. Preparation and Brief	
2. Concept Design	
3. Developed Design	**31-30 00 00 Criteria Definition Phase**
4. Technical Design	**31-40 00 00 Design Phase**
	31-50 00 00 Coordination Phase
5. Construction	**31-60 00 00 Implementation Phase**
6. Handover and Close Out / Operation	**31-70 00 00 Handover Phase**
7. In Use	**31-80 00 00 Operational Phase**
	31-90 00 00 Closure Phase

Coordination and in consultation with the project team, under the supervision of the *BIM Management (control)*. Based on these requirements (red arrows), the domain models are created in the design phase and merged in the coordination model (turquoise arrows in the design phase). The bidder information completes the domain models (turquoise arrows) during the procurement phase. During the construction phase, the domain models are updated according to the as-built status (purple arrows). *BIM Overall Coordination* hands over this as-built documentation is handed over to the facility management (as AIM) (red arrow) according to the client's requirements (or according to a use case).

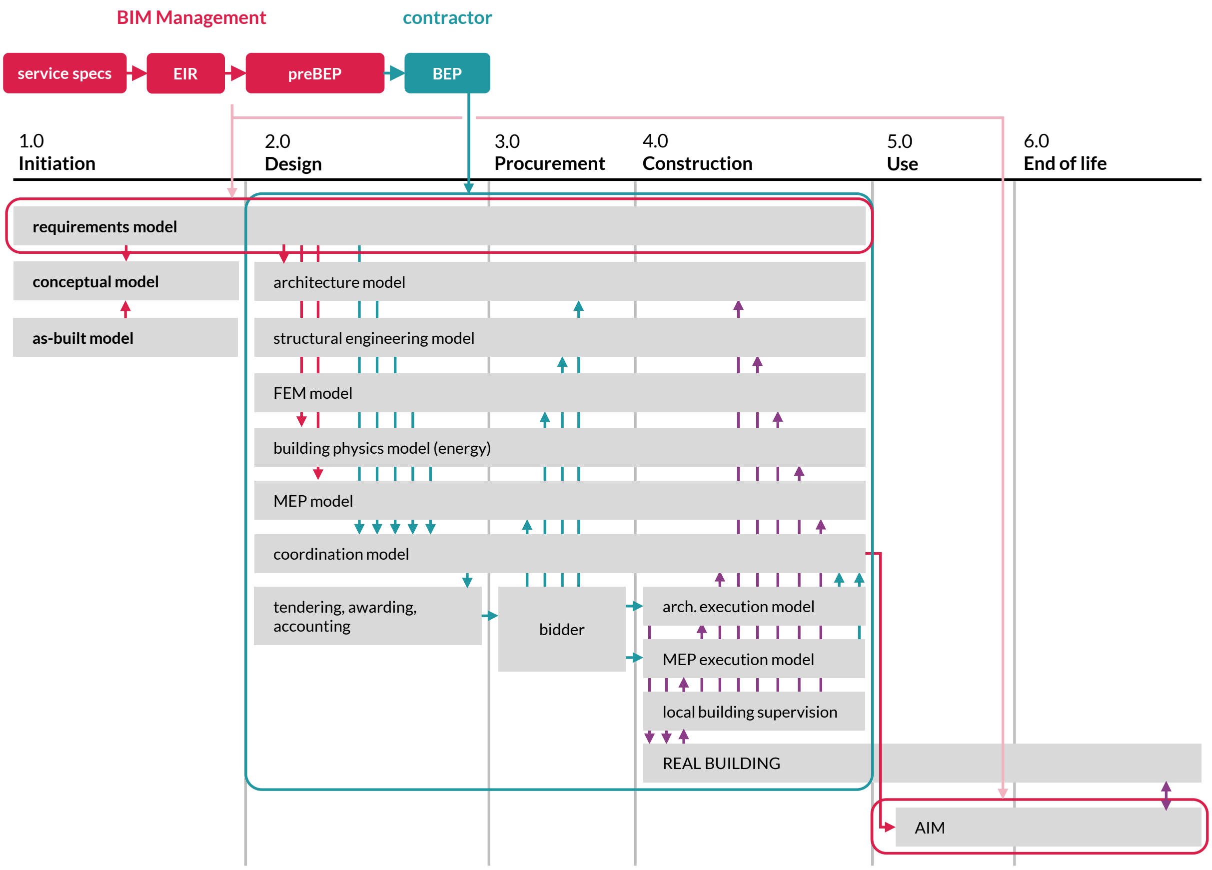


Fig. 4.5: Development of the models during the phases of a building (phases according to EN 16310)

Model **BEP → pre-BEP → BEP**

Various organisations provide a sample BEP as a template for further use in various projects. The *BIMcert Handbook* refers to such sample BEPs where appropriate. The client or *BIM Management* will often create a pre-BEP using a sample BEP based on the *Client's EIR*. This is a project-specific sample BEP; it contains the specified structure and specifies the requirements from the *Client's EIR*. The contractor's project team prepares the BEP on this basis.

4.1 Project initiative

The »Initiative« phase (according to EN 16310) is about basic project development. In this phase, the client develops the basic specifications on which the future project will be based. During the process described in this section, the general decision-making process for project implementation takes place. The results achieved are used to evaluate the extent to which the project idea can actually achieve the objectives and framework defined by the client, and to assess which capabilities can be expected.

4.1.1 Determining the project-related objectives

This activity is carried out at an early stage by *BIM Management (client)* and is designed to focus the work of future contractors on client's benefit.

The *first step* is for the client to define the strategic objective. The client formulates the investment objective, which outlines the reasons for the intended investment. In addition to purely quantitative specifications for the investment framework, qualitative specifications are also defined:

- strategic intent of the client,
- definition of the investment type,
- determination of the intended use,
- determination of the intended service life (staggered according to primary system, secondary system/MEP, expansion),
- definition of operational objectives,
- definition of economic objectives,
- definition of the implementation strategy (form of construction contract), and
- specification of standards to be met or intended real-estate certifications
    - e.g. building certification according to the EU taxonomy (DGNB, BNB, ÖGNI, SGNI).

The *second step* is to define the operational objective which builds on the framework of the strategic objective. The client formulates the BIM objectives, which show the reasons for using BIM. Usually, each defined objective is accompanied by a compact description of the mode of action.

The *third step* is to prioritise the defined operational goals. This can be done by simply prioritising the operational objectives according to their importance to the client. Or it can be supplemented with an objective matrix which compares statements on design-relevant issues, some of which are mutually exclusive. The client's preference clarifies the 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.

Defining the objectives is an essential building block of the project concept. On this basis, the required *use cases* are identified and prioritised during initiation (see Section 4.2). These in turn serve as the basis for identifying the required model content (LOG and LOI) and documentation (DOC) according to the definition of the LOIN. This procedure controls the overall direction of the project, particularly regarding the requirements of future users. 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 the market participants* (with the resulting field of bidders).

The client's BIM objectives are formalised in the BEP. The objectives and uses in each phase of the project are recorded in the BEP in the form of a use plan. The use plan serves as an agreement between the client and the contractor and enables the defined objectives to be translated into concrete uses or applications. The objectives are defined at a higher level, such as sustainability and economy. The applications through which these objectives can be achieved are allocated accordingly. Examples of such applications are the creation of plans, the creation of lists, and the determination of quantities. This structure provides a clear and efficient way of achieving the objectives.
The applications described in this way can serve as a starting point for the precise description of *use cases* (see Section 3.9). In the pre-contract BEP (from pre-contract: before the contract is awarded), the supplier responds to the project-specific design and contracting parties and demonstrates its capabilities in dealing with the BIM method. The decision-relevant content to be answered must be objectively verifiable and/or measurable by the client and labelled accordingly. The aim is to create mutual clarity in the dialogue between client and supplier on the key issues of information management and information delivery prior to contract award. Further clarifications and additions will be made in the BEP after the contract has been awarded.

4.1.2 Determining the financing model

This is done at a very early stage by *BIM Management (client)* and serves to align the project deliverables with the market requirements. The client seeks an optimal mix of required BIM services (with usable added value) and the real capabilities of market participants (with the resulting field of bidders).

4.1.3 Coordination of performance indicators

The performance indicators are agreed at a very early stage by the *BIM Management (client)* and are used to determine the success of the project implementation.

Key Performance Indicators (KPIs) are usually standardised for clients with in-house BIM project expertise. This makes it possible to compare different buildings, structures, and properties.
In Germany, these are usually award criteria that examine economic and financial performance as well as technical and professional skills.

The *first step* is for the client to define the *target area for measurement*. The already developed objectives are used, and a distinction is made between content and process objectives. In the *second step*, the client defines the *relevant measurement parameters and criteria* for the target areas.

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

Roles according ISO 19650 for project delivery
ISO 19650 (series) basically describes the organisation and digitisation of information (information management) in the context of the BIM methodology for the creation of building information. It introduces terms relating to stakeholders in the information management process. In this context, the client can be understood as an *appointing party* who is making an order in the form of work, goods, or services for their building (asset). However, an appointing party can also be a Contractor who requests information from his sub-contractors. In ISO 19650, the *appointed party* is the actor who delivers the information (work, goods, or services). Therefore, information can be delivered by the *Design Contractor* as well as by the *Construction Contractor* and its sub-contractors. For example, when information is delivered by a general planner or general contractor, ISO 19650 distinguishes between the parties using the terms »*lead appointed party*« and »*appointed party*«. In this context, the general planner or general contractor is referred to as the »*lead appointed party*« in relation to the *appointing party (client)*. The *lead appointed party* receives its information (work, goods, or services) from its involved appointed parties (sub-contractors). The term »*lead*« may be used to distinguish between the parties.

4.2 Project initiation

The »initiation« phase (according to EN 16310) is used for the basic project set-up. In this phase, the client develops the basis for the project implementation on which the activities of the contractors are based. This phase starts after a positive evaluation of the project idea. During this 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 phase concludes with the establishment of the BIM organisation, the BIM implementation documents, and the relevant steps for *evaluating the specifications* **before** the immediate **start of design**.

4.2.1 Identify and compile project-related requirements

Initiation starts with the identification of project-related requirements by *BIM Management (client)* and serves to compile these requirements based on any company-wide, cross-project sets of rules. In general, these are declared in the EIR (cross-project). For clients with in-house BIM project expertise and complex requirements, the OIR, PIR, and AIR are based on predefined company-wide specifications. In both cases (cross-project EIR or OIR, PIR, and AIR), the general BIM-related framework specifications for project implementation and for any data transfers (in particular to the AIM) are declared in a standardised manner across all projects.

Interaction between the EIR and the OIR, AIR, and PIR is governed by ISO 19650-1. Accordingly, the OIR (with its specifications for project organisation, in particular BIM organ-

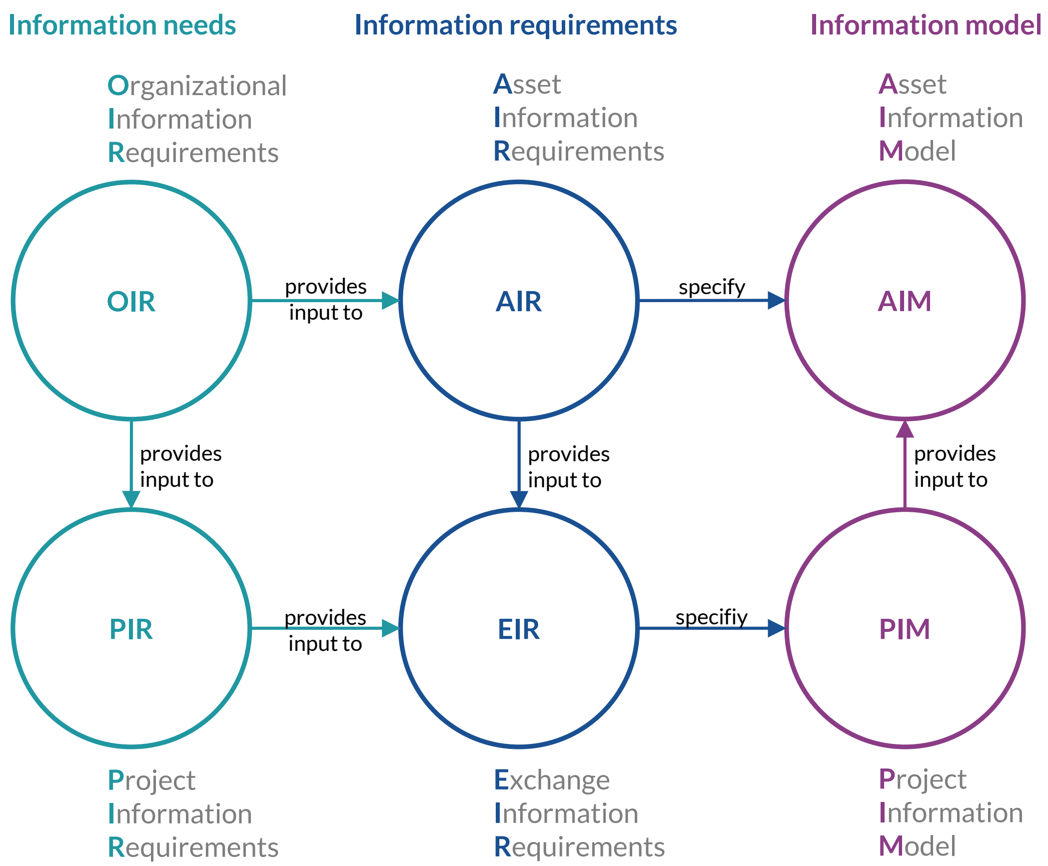


Fig. 4.6: Sequence and depencies of information requirements

isation) and the PIR (with its specifications for project implementation, in particular use cases) serve as a prerequisite for the creation of the AIR, which contains the specifications for the transfer of model data to the Asset Information Model AIM (in particular data structure). The EIR is produced based on the specifications in the OIR, AIR, and PIR, and includes the specifications addressed in these documents.

The *first step* is to identify relevant *regulations (BIM implementation documents)*, *client's specifications*, and *normative requirements*. The project location, the project complexity, and the corresponding objectives of the client are key criteria for narrowing down the scope.

The *second step* is to summarise these *requirements on a project-specific basis*. They are now available as a basis for the subsequent project-specific creation of the BIM implementation documents. Here, too, the requirements relevant to the project are narrowed down, depending on topology requirements and project complexity. Irrelevant specifications would therefore potentially confuse bidders or lead to excessive services definitions in the bids – this should be avoided.

4.2.2 Creating and setting up the BIM service specifications, BIM implementation documents, contracts

In this activity, *BIM Management (client)* formulates the specific project-related requirements into a set of BIM implementation documents. On this basis, the service specifications for the contractors are declared in a form that is customary in the market and uniformly comprehensible. They form part of the tender and are later also considered part of the planner contracts.

The *first step* is to define the intended *BIM organisational structure (BIM roles and functions)* as a BIM-related part of the project organisational structure. This directly impacts the services to be provided by future contractors – but also considers the client's staffing options and strategic requirements. These are explained in the OIR for clients with in-house BIM project expertise. The BIM organisational structure also depends on the intended delivery strategy (construction contract form) of the project (see Section 4.1.1).

The *second step* is to define the *service specifications* for all relevant *BIM roles* (BIM organisational units) – often carried out in the overall context by *BIM Management (client)*, *BIM Management (control)*, *BIM Overall Coordination*, *BIM Domain Coordination*, *BIM Modeller*, and local construction supervision, to fully coordinate and clearly delimit the service specifications. As a basis for this, core services and optional services from the service specifications may be used and compiled for the specific requirements of the project. As a result, *BIM Management (control)* can be commissioned to support the *BIM Management (client)* in the operational implementation of the project initiation – in organising the review meetings and setting up the collaboration platform. As the *BIM Management (client)* is active across several projects, delegating tasks to the *BIM Management (control)* allows it to be relieved and deployed more broadly across several projects.

At present, BIM organisational units (roles) are often still staffed by separate specialists. However, it is foreseeable that the necessary BIM skills will be provided directly by existing organisational units in the future. For example, *BIM Management (control)* services will be provided directly by the project management team. The 2023 edition of the service model/remuneration model for object design – architecture includes standardised BIM services for the contractor's *BIM Overall Coordination* and *BIM Domain Coordination* roles, which are already integrated into the conventional service specifications for object design and architecture.

In Germany, the guidelines VDI 2552 Part 2 and VDI 2552 Part 7 contain specifications for the roles and service profiles.
The HOAI (Official Scale of Fees for Services by Architects and Engineers) is currently being amended in Germany. The 1st amendment stage has been completed. In an expert procedure, the design areas of the HOAI were evaluated and proposals for changes were developed. Since the last reform, design and construction requirements have evolved. For this reason, issues such as sustainability and climate protection, construction in existing buildings and, in particular, the use of digital methods must be given greater consideration in the HOAI. In the first phase, the service specifications were synchronised and updated, new service specifications were added (urban design) and a standard BIM process was developed.

In the *third step*, the client prepares the *Client's EIR* (based on the service specifications). They define and include at least the following specifications:

- description of the use cases relevant to the client (possible basis PIR),
- specifications for the *data structure* (possible basis AIR),
- specifications for the levels of detail (possible basis OIR),
- specifications for the project location and structuring (possible basis OIR),
- requirements (possible basis OIR) for the
  - interfaces to be used,
  - names/designations to be used,
  - data transfers to be carried out, and
  - *collaboration platform* to be used.

Clients with in-house BIM project expertise can create the above requirements based on the higher-level specifications in the PIR, AIR, and OIR.

The *fourth step* is the preparation of the preBEP, which serves as the basis for the project setup during the EIR/preBEP review meeting (see Section 4.2.8 and Section 4.2.9). The preBEP builds on the project-related *Client's EIR* and specifies it in terms of the exact sequence for implementing the EIR specifications. The chapter structure of the *Client's EIR* is maintained in the BEP to provide a direct link to the specification between the *Client's EIR* and their implementation in the BEP.

The final step is to integrate the developed specifications into the tender documents.

4.2.3 Model-supported requirements design (requirements model)

BIM Management (client) and *BIM Management (control)* now formulate the project-related requirements for the asset to be created. The difference to a conventional room and function programme lies in the semantics of model-based requirements design and the associated machine readability. This allows the seamless transfer of the client's specifications by the design team (= *Design Contractor*) into the respective BIM software applications as well as the automation-supported checking of the specifications from the requirements model against the current design status during the project. It also ensures the subsequent reusability of the information generated by the *Design Contractor* in the operation phase (as AIM). The requirements model is a performance specification for the *Design Contractor* and is therefore part of the tender.

For Austria, the requirements model is listed in Annex C (Table C.1) of ÖNORM A 6241-2. This model type only contains rooms (IfcSpace), these are made available to the designer as an IFC model and contain, for example, the room and function programme of the tender (or competition). The requirements model is created and updated in an application for digital room books. It is retained throughout the project and is used at the start to provide basic information to the architecture authoring software and as a control model for further design as the project progresses.

Requirement models are created using specially developed tools such as dRofus or BuildingOne. These tools enable the concentrated development of room and function programmes and the corresponding organisation of space types, including equipment options. They can map these specifications into an IFC-based structure. The specifications for the IFC structure are taken from the AIR or the *Client's EIR* and must conform to the data structure in the BEP to be used later in the project by the *Design Contractor* (see Section 4.2.2). Otherwise, a comparison between the requirements model and the design models will be difficult or impossible.

The requirements model maps all spaces to be considered in the design (or at least the required room types) including the respective qualities to be created. These are then responded to by the *Design Contractor*. The requirements model can be initiated by the *Design Contractor* and updated as the design progresses. The original requirements model remains the responsibility of the client and is updated by *BIM Management (client)* where appropriate. A change to the requirements model is traceable and communicated accordingly. In certain circumstances, this change is a formal amendment to the contract and may result in a design change. The interaction between the design specification and design implementation thus becomes more transparent and comprehensible.

The requirements model is compared with the design models at least during the data delivery checks (reaching a quality gate).

4.2.4 Basic structure (surveying, as-built model, terrain model)

BIM Management (control) (possibly together with the *Surveying* team) creates the project-related design basis during the basic design. The difference to the conventional approach lies in the significantly higher precision of the specification (geo-positioning, complete mapping of the existing situation, structural specification, and functional scope). In any case, the baseline must include the results of the actual as-built survey (e.g. point cloud of a laser scan). The as-built models for the terrain and any existing buildings based on this survey can also be created later by the *Design Contractor*. This facilitates the seamless use of as-built information by the *Design Contractor* in their BIM software applications. If the as-built and/or terrain model are part of the tender, as it may be required as the basis for any conceptual studies or architectural competitions, it makes sense to have it produced by the *Surveying* team. In any case, the requirements of the *Client's EIR* must also be considered to ensure continued usability.

4.2.5 Tendering, awarding, and installation of the collaboration platform

During the initiation phase, *BIM Management (client)* and *BIM Management (control)* provide the central platform for information exchange: the collaboration platform (CDE). Clients with in-house BIM project expertise use predefined, company-wide standardised product specifications as the basis for all projects.

The *first step* is for the client to identify the *relevant functions*. The key criteria here are user rights, the resulting security issues, the type and complexity of the client's project, and the intended delivery strategy (form of construction contract).

The *second step* is to summarise 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 according to the specifications.

Once procurement has been completed, the *third step* is t*o set up the project*. This is done by the *BIM role* that will later be responsible for monitoring and controlling the project delivery activities (usually *BIM Management (control)*).

Currently (2024), 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 a direct connection of BIM applications to the collaboration platform and seamless information exchange. The manual steps of providing and receiving information are eliminated. This significantly accelerates and supports collaboration during project execution.

4.2.6 Tendering and awarding of design services

BIM Management (client) and *BIM Management (control)* now identify the best bidder for the design services. The *first step* is to *compile* the previously developed *basics* (regulations, specifications, requirements model, as-built basis).

The *second step* is to determine the *most suitable tendering strategy* in the context of BIM (single-stage, two-stage, loaded, open). The current market environment needs to be compared with the required scope of services / service profile. The aim 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.

The *third step* is to develop the *specific tender criteria* (*openBIM*, proof of qualification of the contractors). The client defines the required qualitative suitability of the bidders (BIM competence, references, BIM applications) as well as the mechanisms for measuring and evaluating them. It is important to ensure that the defined requirements allow for a broad range of bidders (i.e. are as low as possible) as well as guarantee *reliable BIM project implementation* (i.e. are as high as possible) – this always requires a compromise.

When tendering the design services, it is important to consider the information delivery strategy of the construction phase services (see Section 4.4). If only the design services are tendered at the beginning, and the authorship of the domain models is transferred to the *Construction Contractor* later in the project, then consideration needs to be given to how the BIM-related services are provided in the construction phase and at the end of the project (handover to operation and use). If the authorship of the domain models remains with the *Design Contractor* (as part of the construction documentation), the service specification must be adapted accordingly to cover the necessary tasks for updating the domain models. The chosen information delivery strategy must therefore already be considered in the tender for the design services.

During the tender and award 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. On the one hand, bidders use questions to *BIM Management (client)* and *BIM Management (control)* to concretise their information about the project. On the other hand, questionnaires are used by *BIM Management (client)* and *BIM Management (control)* to check the BIM competence of bidders.

Once the design services have been awarded, the interaction between the client and the contractor takes place in accordance with ISO 19650, based on the contractually binding specifications (service specifications and EIR).

4.2.7 Conduction of model-based studies/competitions

This activity is prepared by *BIM Management (client)* and *BIM Management (control)* during the 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.

ÖNORM A 6241-2 Annex C already defines a BIM requirement for this phase, which provides for conceptual models (envelope models) with a storey structure.

4.2.8 Organisation of the design team / Design Contractor review

In parallel with the ongoing design contract negotiations, the *Design contractor* is introduced to the project principles. This introduction takes the form of a joint review meeting. The review meetings are led by the *BIM Management (control)* and serve to assess the actual BIM capabilities of the *Design Contractor* (qualification) according to ISO 19650 as a **capability and capacity review**. In case of increased time pressure, the reviews can also be carried out after the design contracts have been concluded. However, any corrective action to *Design Contractor*'s qualification after the contract has been signed will not affect the fee. In the contract negotiations, the *BIM Management (client)* and the client need to ensure that any deficiencies in BIM skills that are only identified in the post-contract review are considered and acted upon. In both cases, *BIM Management (control)* will require corrective action to be taken in the event of apparent deficiencies in the BIM skills. These usually consist of catch-up training (e.g. software or role qualification). The *BIM roles* involved are shown in Fig. 4.7.

The reviews are carried out in three stages: the **EIR/BEP review**, the **modelling review**, and the **project specifics review**. Prior to the reviews, the full scope of the developed baseline (regulations, specifications, requirements model, as-built basis) is presented to the *Design Contractor*. This is necessary to clarify all relations and requirements by mutual agreement and to establish a common understanding of the project requirements for implementation by the entire project team.

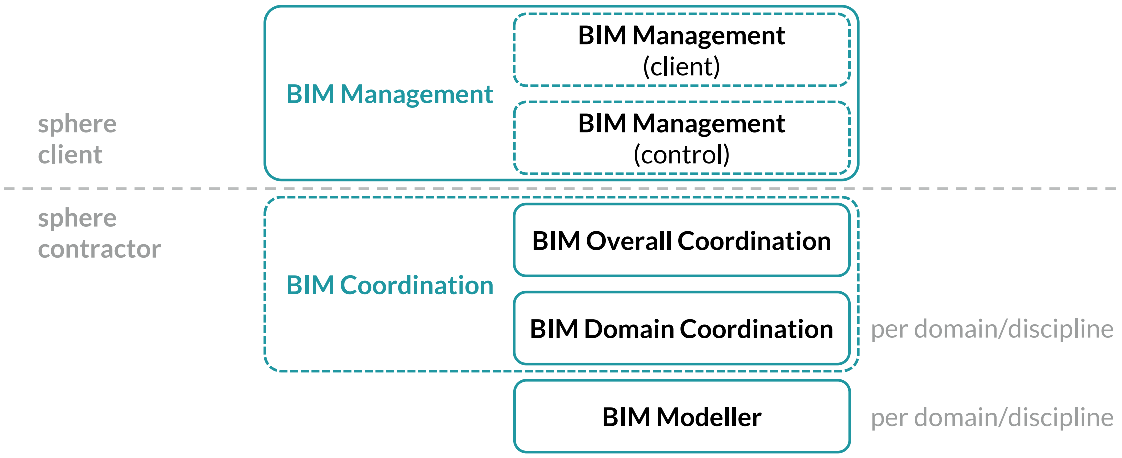


Fig. 4.7: BIM roles (functions) relating to the client sphere and the contractor sphere

The former name of the reviews was colloquia (BEP colloquium and modelling colloquium). As the term colloquium is understood differently in different countries, the name was changed. In contrast to a colloquium, the reviews have a concrete structure and a clear objective (development of the design team and its evaluation).

EIR/preBEP review – In the first review, *BIM Management (control)* presents the developed BIM implementation documents to the future *Design Contractor* (participation of *BIM Overall Coordination* and individual *BIM Domain Coordinations* is mandatory). At this stage, usually only the *Client's EIR* is available; due to the greater depth, the associated preBEP may also be presented if available. The aim is to achieve a common understanding between the client and the *Design Contractor* about the requirements of the project. In particular, the structure of the BIM implementation documents, the tasks/responsibilities of each *BIM role*, the individual use cases, and annexes are discussed. *BIM Domain Coordinations* and *BIM Overall Coordination* may provide feedback and make additions to this, including:

- selection of staff for the required *BIM roles*,
- adaptation of the domain model content (e.g. separation of the terrain/surroundings into an own domain model), and
- other use cases for *Design Contractors*.

BIM Domain Coordinations and *BIM Overall Coordination* may also submit adaptation proposals. These may include:

- suggestions for improvement in the implementation of a use case and
- concretisation of domain-specific regulative specifications.

All additions and proposed adjustments are logged and reviewed by *BIM Management (control)*. Practical experience has shown that approximately half a day is recommended for the duration of the EIR/preBEP review.

Modelling review – The second review is to ensure model-based collaboration on the project. It is led by *BIM Management (control)* and requires the participation of *BIM Overall Coordination*, individual *BIM Domain Coordinations*, and *BIM Modellers*. As part of the review, a previously defined section of the project (for competitions or existing projects, otherwise a fictitious test scenario) is modelled by *BIM Modellers* according to the BIM implementation documents for each domain. The specifications are defined by *BIM Management* *(control)*. This includes the mapping of LOG and LOI content that corresponds to a later point in time (e.g. design) and not only contains the official IFC data schema (including the creation of individual property sets and properties). One use case could be the *coordination of overall coordination meetings*.

Modelling starts with the architecture domain model, whose *BIM Domain Coordination* then checks its own domain model for compliance with the LOG and LOI specifications as well as for other quality criteria (e.g. internal collisions in the domain model) and passes the pre-checked domain model, including the check report (.bcf comments), to *BIM Overall Coordination*. At the same time, the architecture *BIM Domain Coordination* transfers the reference models to the other *BIM Domain Coordinations* (e.g. structural engineering, building services).

BIM Domain Coordinations check the import of the reference models and may provide feedback. Once an appropriate setting (for the recipients) has been verified for the export of a reference model, this is recorded as a transfer configuration (see Section 4.3.3) for inclusion in the BEP. The other domain models can now be created by the *BIM Modellers* for each domain based on the reference model. These will also be pre-checked by their *BIM Domain Coordination* for compliance with the LOG and LOI and submitted to *BIM Overall Coordination*, including the check report (.bcf comments).

BIM Overall Coordination then transfers the provided domain models to its *coordination model*. There, it checks the domain models against each other (for compliance with the LOI and for internal collisions) and across domains. It creates issues for any deficiencies found and initiates an *overall coordination meeting*. At this meeting, the deficiencies are discussed and the check report (.bcf comments) is sent to the relevant *BIM Domain Coordinations*. The BCF comments are transferred to the authoring software and the issues are checked for feasibility (e.g. correct display of the image section).

This process is used to ensure the basic feasibility of the specifications, as well as to define relevant content for model-based collaboration within the *Design Contractor*.

These include

- ensuring the use of a *uniform project location / project direction*,
- ensuring the use of a *uniform storey structure and grid structure*,
- detailed coordination of the *IFC transfer configuration* (see Section 4.3.3) in the context of the BIM applications used to ensure the intended collaboration,
- ensuring the required knowledge for model creation / model transfer (modelling and implementation of the LOG and LOI specifications according to the LOIN specification), and
- ensuring the required knowledge for model coordination / model communication.

These steps must be completed prior to design to avoid confusion between BIM setup and design implementation.

All additions and proposed adjustments to the BIM implementation documents are recorded and reviewed by *BIM Management (control)*. Practical experience has shown that approximately one day is recommended for the duration of the modelling review.

Project specifics review – As the reviews are usually not carried out in direct succession and can be spread over several days, the final review meeting is used to clarify any final project-specific issues with the *Design Contractor*. This gives the *Design Contractor* sufficient time to identify any issues that may have arisen in the interim and clarify them with *BIM Management (control)* during the final review. The final review is also conducted and recorded by *BIM Management (control)*. The participants are *BIM Overall Coordination* and all *BIM Domain Coordinations*.

Finally, all recorded comments/additions/adjustments are checked for consistency and feasibility by *BIM Management (control)* and updated in the BIM implementation documents. The BIM implementation documents are then submitted to *BIM Management (client)* for review and approval. If approved by *BIM Management (client)*, the BIM implementation documents become the responsibility of *BIM Overall Coordination* as basis for the BEP.

Based on all three completed reviews, the **Project Information Model** (PIM) can now be established in the design phase.

4.2.9 Verification of the Design Contractor's qualification

As the *reviews* take place during the negotiation of the design contracts, they will provide an opportunity for *BIM Management (control)* to review the *Design Contractors*' qualifications in detail. *BIM Management (control)* will provide *BIM Management (client)* with the *results of all reviews*, including an assessment of the *Design Contractor*'s capabilities. In particular, the modelling review offers an opportunity to gain insight into the existing communication and software skills of the *Design Contractors* per domain: Deficiencies in communication skills or in the use of the *Design Contractor*'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 *Design Contractor* of an individual domain is unwilling to do this, *BIM Management (control)* must inform *BIM Management (client)*. This will directly impact the negotiations and may lead to the exclusion of a domain.

The reviews should be repeated if additional project participants are added during the project phases to ensure smooth interaction between the participants and to be able to identify and resolve any problems at an early stage.

4.3 Design (planning)

The »Design« phase (according to EN 16310) is used to develop the design specifications for tendering, procurement, and construction. The design phases include the preliminary design, the design, and the submission design including the permission process. This section provides a standardised view of the content and services to be delivered in these phases. In general, there is no difference between the basic services and use cases within the design phases – only the scope of the services increases in each successive phase due to the phase-related specifications. All requirements regarding the content to be delivered and the services to be performed are to be defined in the *Client's EIR* and BEP before the start of design (see Section 4.2.8) by the *BIM Management (control)* and *BIM Overall Coordination* and can be further differentiated during the project.

This section considers the steps and definitions required at the start of the design process and describes the use cases usually performed in projects by *BIM Overall Coordination*, *BIM Domain Coordination*, and *BIM Modeller* during the work to be performed.

4.3.1 Handover of the basis models and documents to the Design Contractor (as-built model, terrain model, requirements model)

At the beginning of the design phases, the *Design Contractors* are provided with the previously determined and generated basics. This is done via the collaboration platform (CDE). The following serve as a basis for design:

- terrain model,
- as-built model (if buildings exist and are to be used further), and
- requirements model.

Depending on the project strategy, the first two models have to be created by the *Surveying* team during project initiation or by the *Design Contractor* at the start of design and are submitted as a 3D model (according to EIR specifications) (see also Section 4.2.4). The valid basis for the creation of the model is the as-built survey in form of a georeferenced point cloud and, if necessary, supplementary design documents (valid as-built drawings, formwork drawings). With the handover of the models, the responsibility also changes from the creator (*Surveying* team) to the *Design Contractor* if the as-built model was created by the *Surveying* team.

In (currently still) rare cases, it is possible for the client's asset management to provide the corresponding inventory records and as-built models from their AIM model – this would ensure the continued usability of the inventory data in design (data circularity).

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

All basis model are delivered as IFC files. However, the as-built model is delivered in the native format of the BIM applications to ensure that further processing by the *Design Contractor* is as loss-free as possible (when created by the *Surveying* team).

Therefore, the BIM applications of the *Design Contractor* need to be known at an early stage (when the model is created), which is not possible on every project, e.g. when conducting architectural competitions. In such competitions, a different strategy is used, in which the performance boundary between *Surveying* team and *Design Contractor* is shifted. In such cases, the *Surveying* team only delivers the relevant as-built data as a georeferenced point cloud, and the *Design Contractor* is responsible for the creation of the as-built model based on this data. The problem of coordinating BIM applications at an early stage is eliminated. Any difference in scope, detailing, and prioritisation in the as-built model are also obsolete. In any case, this approach needs to be considered in the service specifications of the *Design Contractor* and hence needs to be decided by the *BIM Management (client)* at an early stage of the project.

Regarding the actual implementation: at the beginning of the design process, each *BIM Domain Coordination* needs to ensure that the supplied basis models may be used correctly by other *Design Contractors* – regarding location (georeferencing) and element definition (IFC entity). Usually, only the architecture domain adopts the terrain model in its authoring software. In the case of as-built models, it can be specified which domain has to implement the corresponding basic information. This depends on whether the as-built model contains the building shell, the extended building stock, or the building services information. For example, the building shell can be assigned to the structural engineering domain, the developed building stock to the architecture domain, and the building services elements to the building services domain. Such a differentiated transfer of as-built model content must be coordinated and defined before the start of the design phase. This is done at the latest when the BEP is prepared in the relevant review meeting (see Section 4.2.8 and Section 4.2.9).

During the design phase, the individual domain models of the domains involved in the project are created based on the basis models.

4.3.2 Stucture of the model basics

The PIM consists of the various domain models of the respective project participants and their domains. These are also referred to as design models. The basis models adopted at the start of design (terrain model, as-built model) remain part of the respective domain models (see Section 4.3.1). During the design phase, the role of overall coordination is often assumed by those primarily responsible for design (e.g. architecture in building constructions).

In Germany, work is underway to create standardised modelling specifications for the various domain models. BIM use cases will then to be added to the basis models.
For example, the modelling specifications of BIM Germany see QR code.

Overarching specifications can be made for all the domain models (in design), which facilitate their coordination and further use. In general, the BEP defines the following information for all domain models:

- clear responsibility/authorship for a domain model and its content,
- the specification for domain model naming,
- the specification of the project coordinates and project direction,
- the specification for storeys and storey zero point,

- the specification for modelling the model content, and
- the specification for the LOIN:
    - the levels of detail (LOG, LOI) and
    - the associated documentation (DOC).

In Germany, understanding of domain models is changing. On the one hand, there are domain models. These contain only the basic information (geometry and alphanumeric). Then there are the BIM use cases. The VDI and DIN have an EE for this, the so-called VDI DIN EE 2552 Part 12.1. This provides a template for describing the processes and the LOIN for each BIM use case (see QR code for an example).

These general requirements 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 their domain model. The respective *BIM Domain Coordination* serves as the responsible role. It ensures the qualitative composition of the provided domain model regarding the specifications. The *BIM Domain Coordination* is the responsible contact role for the coordination and implementation tasks. Different model content must be created for each domain model:

- Architecture domain model:
    - architecture design incl.
        - outdoor facilities,
        - interior design,
        - fire protection, and
        - building physics,
- structural engineering domain model:
    - structurally relevant construction elements (load-bearing), and
- MEP domain models (subdivided into individual domain models):
    - domain model MEP design/heating and cooling,
    - domain model MEP design/ventilation,
    - domain model MEP design/sanitary/plumbing,
    - domain model MEP design/electrical design,
    - domain model MEP design/ICT planning, and
- other domain models depending on project requirements.

At the start of the project, the allocation of the domain models made by the *BIM Management (control)* is reviewed once again with the *Design Contractors*. It is possible to adapt the content of the domain models at level of:

- domains
    - e.g. the domain model of the outdoor facilities or the interior design can be defined as an independent domain model of the architecture (separate from the actual architecture domain model) and
- specific domain model elements:
    - e.g. it can be decided together with the electrical design whether specific actuators (entity IfcActuator), which are used to control model entities in other domain models, are transferred to the domain model of the electrical design or remain in the other domain model and the electrical design contributes the necessary information purely alphanumerically. Such complex

dependencies need to be controlled by dedicated coordination processes – these should be specified in the BEP in separate use cases. Identical elements should only be present in different domain models if they are used for mutual coordination or synchronisation (e.g. load-bearing elements in the architecture domain model and the structural engineering domain model, or toilets in the architecture domain model and the domain model MEP design/plumbing).

Model information from project participants who do not maintain an independent domain model can be transferred to the model-managing domain using BCF comments. For example, fire protection and building physics can deliver their information to architecture this way. The responsibility for the content of the information remains with the delivering domain. The receiving domain is only responsible for the implementation of the information in the model (this is checked by the respective *BIM Domain Coordination*). Thanks to BCF communication, this process is optimal for both sides – each model change can be tracked by a corresponding change request, and the implementation status of each change request is transparent.

Specification for domain model naming
Each domain model (including any sub-model) must have a unique name. The name is consistent over the entire project: it contains neither date nor version information. The CDE regulates these two indicators (date of upload and versioning systems within the CDE).

The *Client's EIR* or BEP must specify the naming of the domain models, usually following a simple coding system. Part of the coding should always be:

- abbreviation of the project,
- abbreviation of the author or the responsible domain,
- abbreviation of the domain model or, if applicable, of the sub-model, and
- abbreviation of the transfer configuration (see Section 4.3.3).

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

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

Fig. 4.8: Example of a naming convention for the architecture domain model

Specification of project coordinates and project direction
All domain models must be transferred in the correct position in relation to each other. The required project coordinates and project orientation (deviation from true north) are defined in the BEP prior the start of the design (see Section 4.2.8 and Section 4.2.9).

ÖNORM A 6241-2, Annex A (normative) specifies the following: *The building model must be provided with a clear reference point, related to the mean sea level height above the Adriatic Sea, and with a vector defining the deviation from the north orientation.*

In Germany, reference surfaces must be labelled with »Height above NHN in DHHN2016«. NHN is for »*Normalhöhennull*« (sea level). DHHN stands for »*Deutsches Haupthöhennetz*« and the number 2016 is based on the integrated geodetic spatial reference from the year 2016 (resolution of the land surveying authorities of the federal states).

In new construction projects, the architecture domain model usually takes on the task of implementing the location (project coordinates) and structuring. It then rolls these out to the other domains during the first transfer of the architecture domain 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-Krueger) while spanning a local compact measurement network with a zero point on the A/1 axis defined for collaboration with the other domains. This enables easy collaboration within the different *Design contractors* and an exact integration of surveying results from the construction site (e.g. point clouds).

Specification for storeys and storeys zero point
In addition to the general definitions of the storey structure, the specific storeys and their names must be defined in the BEP on a project-specific basis at the start of design and implemented equally in all domain models. All domain models must have a uniform storey structure. Any deviation in the name (including storey code), number, or storey height between the individual domain models (transferred via IFC file) is not permitted and is the responsibility of the respective *BIM Domain Coordination*.

Important: Additional storeys/reference planes may be used within the native domain models; however, these may not be passed on.

ÖNORM A 6241-2, Annex A (normative) specifies the following regarding the use of storeys: *The level of a storey shall always be at the same height. The distance between storeys shall be greater than 1.50 m (see ÖNORM EN 15221-6).*

The reference point of each storey (storey zero point) must also be defined in the BEP. For new construction projects, this can be defined by the top edge of the storey or the top edge of the slab. For projects on existing buildings (e.g. renovation, refurbishment) the storey reference level can be defined as follows if the top edge of the slab cannot be determined or the top edge of the storey is not continuous within a storey:

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

ÖNORM A 6241-2, Annex A (normative) specifies the following: *The reference level of the storeys is linked to the respective top edge of the slab (storey without floor screed).*
This applies mainly to new construction projects:

- The top edge of the bare ceiling (slab) is to be used as the zero point of a storey.

Specification for modelling the model content
The compilation of project-related use cases takes place in the *Client's EIR* and BEP. A use case is defined as the model-based execution (application of the BIM method) of specific activities according to defined requirements to support one or more objectives in the life cycle of a building. The LOIN (Level of Information Need) is determined from the project-related use cases. This includes the formulation of the geometric (LOG) and alphanumeric (LOI) content requirements for the domain models for data exchange and the re-use of this model data, as well as the determination of the documentation (DOC) required for each use case.

In the design phases, the intended content of the LOG and LOI is transferred to the domain models in the relevant authoring software by the *BIM Modeller* as the domain model content is created. It is advisable to define modelling specifications in the BIM implementation documents; these can be presented as technical guidelines in the annex to the BIM implementation documents.

The following core 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 is beneficial to the entire design team.

ÖNORM A 6241-2, Annex A (normative) also provides a clear representation of the structure of the elements to be modelled.

ÖNORM A 6241-2, Annex A (normative) also specifies that: *All building elements are to be subordinate to the storey structure since their construction and use is based on the accessibility of people.* This means that

- the model elements are to be modelled storey by storey (connection to the original storey and no extension beyond).

In Germany, work is underway to create standardised modelling specifications for the various domain models. BIM use cases will be added to the basis models. See QR code for example modelling specifications.

4.3.3 Organisation of collaboration

The actual model-based collaboration begins with the first transfer of domain models. *BIM Overall Coordination* uses the domain models for the coordination of these models. Furthermore, each domain can add the domain models of another domain in its own software as a reference (reference model) or independently interact with the domain model data in a checking software for coordination by the *BIM Domain Coordinations*.

Initially, the focus is on the correct location (project coordinates) and structuring of the domain model. However, the focus quickly shifts to the actual design content, which can be captured more quickly than in the conventional design methods (2D drawings) thanks to the three-dimensionality of the model data. It should be noted here that not only comprehensive domain models or domain models authorized by *BIM Overall Coordination* can be used as reference models between the domains, but also domain model sections or intermediate states can be employed selectively for situational coordination (both in the authoring software and in the checking software) of the *BIM Domain Coordination*.

To be able to carry out model-based collaboration, some basic requirements must be defined in the BEP. These include the coordination within a phase, the *coordination at a phase end/milestone*, the type of coordination between the project participants, and the compilation of the models to be delivered.

For ongoing coordination, a so-called *coordination plan* is required in the BEP, which defines the coordination at *overall coordination meetings* and the associated scope of data delivery. The *coordination at a phase end/milestone* should be defined in the BEP by the *information delivery plan* (as a information delivery milestone according to ISO 19650-2). This is like the coordination at *overall coordination meetings*. But here quality gates must be achieved in the model checking since *BIM Overall Coordination* must issue a release.

In both cases, domain models are supplied. However, to ensure that the IFC models are always exported in a consistent form, transfer configurations should be defined in the BEP.

Transfer configuration
The first concrete transfer configurations are defined during the review meetings (see Section 4.2.8 and Section 4.2.9) zat the beginning of the project. They help to consider the different uses of the models in terms of the necessary export settings in the authoring software and to ensure the necessary content of the models when they are transferred. Further necessary transfer configurations can be added to the BEP if additional project participants are added during the phases, software updates are carried out, or requirements regarding the model content change.

A transfer configuration must

- have a unique name (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, breakthrough model, reference model, etc.),
- 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 multilayered components (e.g. composite, broken down into individual elements).

VDI/DIN-EE 2552 Part 12.1 provides information on transfer configurations.

Coordination plan and information delivery plan
A *coordination plan* is created for the coordination of the *overall coordination meetings* in the BEP. It describes the structure of the data to be transferred in relation to the phase (whose requirements result from the use cases in the BEP) for the *coordination meetings* to be held (see Section 4.3.5). This data must be provided by the respective *BIM Domain*

Coordination on the collaboration and communication platform. According to the *coordination plan*, the following must be transferred:

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

The data is always sent to *BIM Overall Coordination* well before a coordination meeting. This ensures that *BIM Overall Coordination* has enough time to carry out its own quality review. The specific dates for the *coordination meetings* must be agreed with and approved by the *BIM Management (control).*

The BEP specifies the *information delivery plan* to distinguish between this ongoing coordination and those at a phase end/milestone. The main difference to the *coordination plan* is the much higher level of checking. This is intended to ensure the actual delivery of the required model content (achievement of a quality gate and authorization of domain models by *BIM Overall Coordination*) and is related to payment releases from the client.

For the *information delivery plan*, the above transfers are complemented by the *BIM Domain Coordinations*:

- IFC domain models;
  - authorized by *BIM Overall Coordination* after the final coordination meeting and
  - according to the specified level of detail (LOG + LOI) in the full development stage,
- drawings dderived from the domain model in PDF and DWG/ DXF:
  - drawings must correspond to the reviewed and approved state of the domain model (IFC file). 2D information contained only in the drawings (e.g. dimensions) must not contradict the information in the domain model, and
- supplementary information (e.g. detailed drawings).

BIM Overall Coordination delivers according to the *information delivery plan*:

- an authorized coordination model (in the format of the checking software),
- a PDF check report, and
- a categorisation scheme for the check results (see Section 4.3.5),
  - incl. allocation to the existence of a required quality gate.

The quality gates determine the authorization of a domain model and the overall model (federation of all domain models, status: authorized on the collaboration platform). The authorization is issued for each domain model on the collaboration platform after it has passed the review of *BIM Overall Coordination*. When all domain models reach this status, the federated overall model is authorized on the collaboration platform. The quality gates are defined for each checking query (checking rule).

This precise categorisation and breakdown per checking query means: If a domain model has a very good LOI status (= fully available), but there are several serious collisions in load-bearing slabs within a domain model, authorization will not be granted. On the other hand, if there are only a few and minor collisions (e.g. between a few non-load-bearing walls and load-bearing columns), authorization may still be granted. It is important to ensure that the categorisation of the quality gates and the check results are presented as clearly and transparently as possible in the *BIM Overall Coordination* check report. As *BIM Management (client)/BIM Management (control)* also carries out random checks for *coordination at a phase end/milestone*, it can also influence the granting of authorization.

BIM Overall Coordination specifies the dates for the *coordination meeting at a phase end/ milestone* and the associated information delivery. They must be coordinated with *BIM Management (control)* and the project schedule.

Coordination cases

The type and extend of coordination between the parties involved in design can be described in the BEP in so-called coordination cases. They belong to the use cases and describe the coordination of the *Design Contractors* in BIM quality management step by step. Depending on the type of coordination, these use cases are carried out over the entire course of the project (see Fig. 4.9).

coordination at phase ends/milestones

responsibility:	BIM Overall Coordination
participants:	BIM Domain Coordination, BIM Management (control)
content:	coordination at the end of a project phase or milestone with all domain models
time:	once per project phase/milestone according to schedule
aim:	data delivery (in compliance with the release process)

part of the BIM Quality Management

coordination at overall coordination meetings

responsibility:	BIM Overall Coordination
participants:	BIM Domain Coordination, BIM Management (control)
content:	regular coordination
time:	ongoing, specified cycle according to schedule (= overall coordination meetings)
aim:	coordination of the domain models

part of the BIM Quality Management

coordination between individual planning participants

responsibility:	BIM Domain Coordination
participants:	BIM Domain Coordination
content:	selective/situational coordination according to a specific need, no overarching coordination
time:	as required, on an ongoing basis
aim:	coordination between two domain models

not part of the BIM Quality Management

Fig. 4.9: Coordination at different points of time

The coordination between the individual design participants is not chaired by *BIM Overall Coordination*; the individual *BIM Domain Coordinations* coordinate directly based on the models. Data is exchanged via the collaboration platform, where both the necessary domain models (even if only in part) and the coordination requirements are communicated in the form of BCF comments. This type of coordination ensures traceable documentation of the adaptations.

The coordination on *overall coordination meetings* and the *coordination at a phase end/milestone* are led by *BIM Overall Coordination*. Both include the preliminary check of the domain model by the *BIM Domain Coordination* (including the check report) and the review of *BIM Overall Coordination* (within and between domain models). While the coordination at the *overall coordination meetings* is continuous for the regular coordination within a phase and therefore progress is monitored by *BIM Overall Coordination*, the *coordination at a phase end/milestone* only takes place at specific times according to the schedule. The quality of the domain models does not need to be completely correct during the ongoing coordination, but at the time of the information delivery, the domain models need to reach a certain quality, which is defined by the use cases at this point in time in the BEP. The achievement of these quality gates is checked and evaluated by *BIM Overall Coordination* and, if the quality is sufficient, recorded by an authorization on the collaboration platform.

The coordination cases listed here have been renamed for a more consistent understanding. The old designation follows the allocation:

- Small coordination case = coordination between individual design participants,
- Medium coordination case = *coordination at overall coordination meetings*, and
- Large coordination case = *coordination at a phase end/milestone*.

Basic conditions for coordination
Regardless of the type of coordination, certain basic conditions must be met and defined in advance in the BEP:

- compliance with the responsibilities per domain model,
- compliance with the defined formats (IFC, BCF, DWG/DXF, PDF, XSL),
- use of the specified collaboration platform (CDE),
- use of the specified communication platform (for BCF),
- use of the specified transfer configurations, and
- compliance with the use cases specifications (see Section 4.3.4).

4.3.4 Performing model management / BIM quality management

The implementation of model management is a use case of the BEP that takes place at different levels of responsibility and depth. These use cases are often referred to as BIM quality management or BIM quality assurance – and are often understood to include the familiar clash detection. However, to fully capture it, further checks are required, as well as the definition of a *coordination plan* and an *information delivery plan* (see Section 4.3.3).

BIM quality management
The *Client's EIR* or the BEP must describe the requirements for model-based quality management and the specific implementation for uniform quality control and coordination of the digital domain models. The description includes the specifications for the checking routines that must be implemented in the checking software.

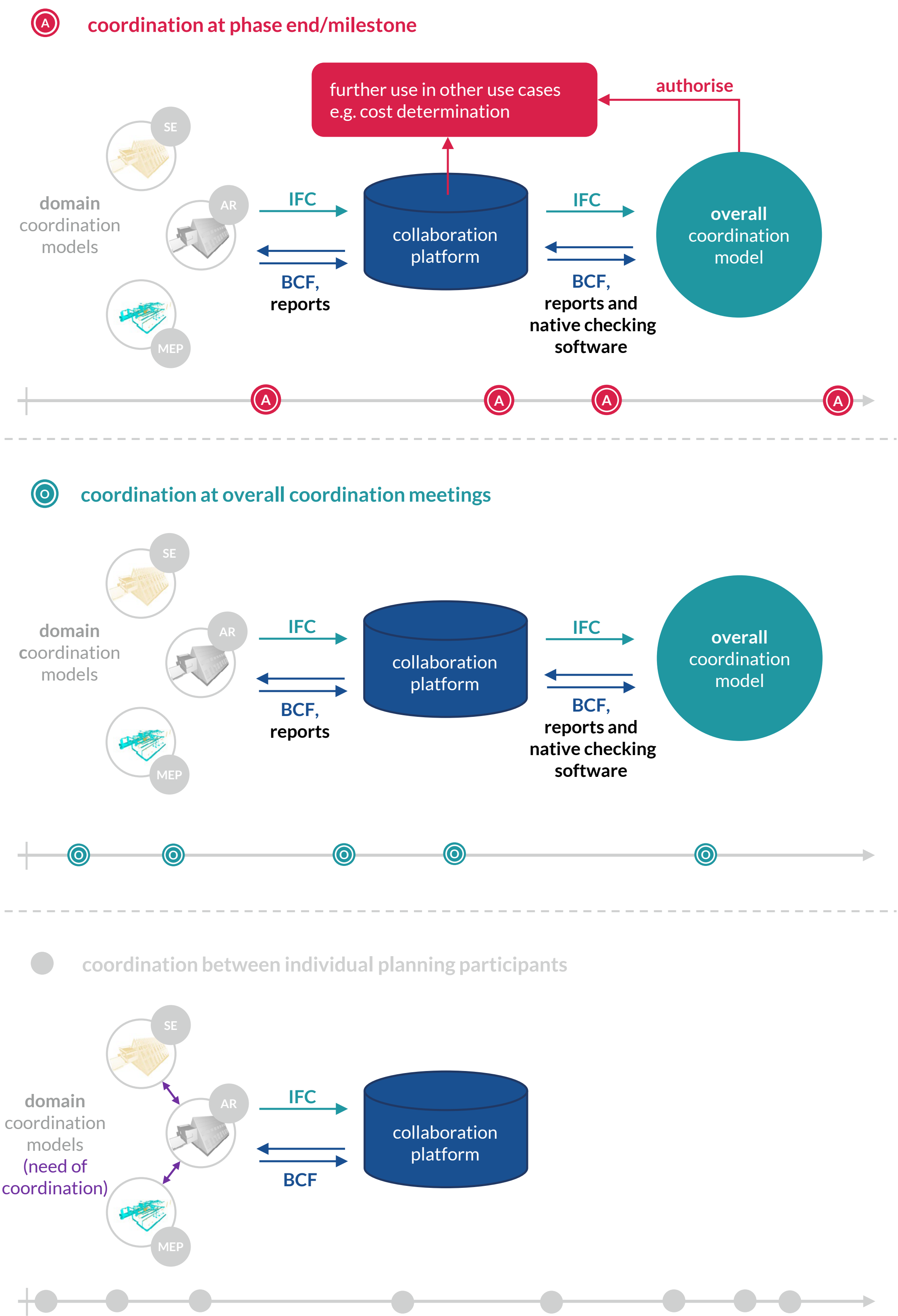


Fig. 4.10: Coordination need at different point of time during the project

The checking routine is the overall definition of the quality management specifications in a checking software. It is essential that a checking routine is always performed in the same way, as the name »routine« suggests. Each checking BIM role has its own checking routine: *BIM Domain Coordination*, *BIM Overall Coordination*, and *BIM Management (client) / BIM Management (control)*.

It consists of checking criteria, their assignment to the BIM role, a classification scheme of the check results for coordination at *overall coordination meetings* and *coordination at a phase end/milestone*, individually defined checking queries (= checking rules in the checking software), and a check report.

Checking criteria
Depending on the type of project and form of collaboration, BIM quality management can cover different aspects of a digital model. Checks may include compliance with data formats used (e.g. IFC4), formal completeness of the required information (e.g. LOI), geometric relations of the elements (e.g. freedom from collision, minimum clearances), or compliance with domain-specific guidelines (e.g. building regulations).

To carry out a check in a coordinated way, concrete criteria (see Fig. 4.11) help to ensure a uniform way of checking without overlooking groups of elements. The checking criteria represent a classification into different focus groups that organise a model checking and make it easier to evaluate the checking results.

The previous checking criteria represented the basic set-up, known as:
- FCC = Formal Criteria Check,
- QCC = Quality Criteria Check, and
- ICC = Integrity Criteria Check-

The checking criteria have been renamed to make them easier to understand. They have also been expanded by:
- MCC = Model Comparison Check and
- CCC = Coordination Criteria Check.

All the above checking criteria are part of the buildingSMART Austria EIR.
This structure and its systematic contents have been developed from 2016 onwards and have been further developed during the different projects (see Fig. 4.11). Today, they can be found in many specifications for checking routines.

Model comparison checking criteria are performed internally for each domain model. The check is informal; an evaluation of the checking results in the check report is not required. The checking queries are intended to provide an overview of the development of the domain model.

The model comparison checking criteria include check queries on:
- comparison of the geometric information of all domain model elements with the previous status and
- comparison of the alphanumeric information of all domain model elements with the previous status.

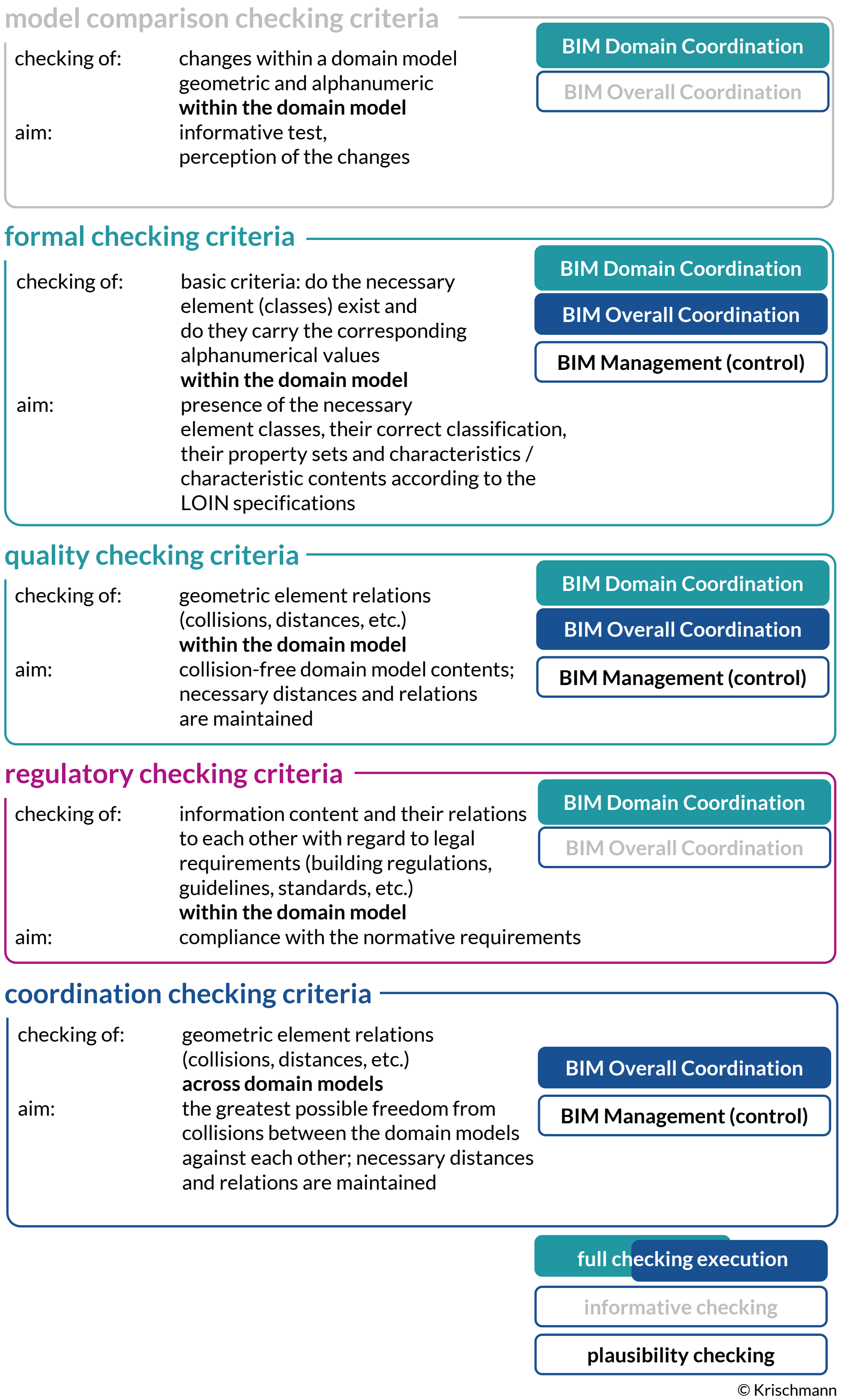


Fig. 4.11: Checking criteria depending on checking type and checking content

Formal checking criteria are performed internally for each domain model. They represent the basic check, as a further check only makes sense for domain models with sufficient formal depth. For example, if the domain models are not in the correct position in relation to each other, a cross-domain model clash detection cannot be performed.

Formal checking criteria include, but are not limited to, checking queries on:

- basic modelling specifications:
  - e.g. is the domain model positioned correctly,
  - e.g. elements are present and relatable to each storey, and
  - e.g. GUIDs are unique,
- level of detail according to LOIN:
  - *LOG*: elements are modelled according to the LOG class, e.g. single or multi-layered, and
  - *LOI*: elements are correctly classified according to their IFC entity and carry the required properties according to their LOI class. The value range of the properties is meaningful (e.g. according to an option specification, contain a number range, contain a true/false value).

Quality checking criteria are performed internally for each domain model if the formal checking criteria have been sufficiently passed. This includes collision detections (internal to the domain model). However, as these queries do not provide a sufficient answer to the geometric state of a domain model, geometric relations are also queried.

Quality checking criteria include checking queries on:

- geometric relations between elements:
  - elements do not overlap (clash detection), or the overlap is within the specified tolerance and
- geometric content relations:
  - elements have a required minimum or maximum distance:
    - e.g. columns are coherently connected at the top and bottom to a supporting structure (slab, ceiling),
    - e.g. minimum distance between plumbing fixtures and shafts, and
    - e.g. maximum distance from shafts in adjacent storeys.

Regulatory checking criteria are defined and performed by the responsible domain. They represent the checking queries that can map model-based specifications from standards, norms, and guidelines. Because of its expertise as a domain designer, this check is the responsibility of the *BIM Domain Coordination*. *BIM Overall Coordination* can be given the checking queries to randomly check compliance.

Regulatory checking criteria include checking queries on:

- mathematically mappable requirements from standards, norms, and guidelines:
  - e.g. width of escape routes,
  - e.g. distances from sockets to washbasins/water outlets, and
- relations of requirements from standards, norms, and guidelines:
  - e.g. required number of accessible parking spaces.

In the case of the regulatory checking criteria, it should be noted that the local and domain-specific requirements of the guidelines or normative standards must be considered.

Coordination checking criteria are performed across domain models by *BIM Overall Coordination*, with *BIM Management (client) / BIM Management (control)* also performing random plausibility checks. The checking queries mostly consist of clash detection, but always represent a query of the geometric element relations. For example, comparing the support structure of the architecture domain model with that of the structural engineering domain model is also a coordination checking query. The architecture domain models are checked for collisions with the building services domain models.

Coordination checking criteria include checks on:

- geometric element reference between building elements and building services elements:
  - architecture or structural engineering against building services heating/cooling,
  - architecture or structural engineering against building services ventilation,
  - architecture or structural engineering against building services plumbing,
  - architecture or structural engineering against building services electrical,
  - architecture or structural engineering against building services sprinklers, and
- geometric element reference between building services elements:
  - building services heating/cooling against building services ventilation, building services plumbing, building services electrical, building services sprinkler
  - building services ventilation against building services plumbing, building services electrical, building services sprinkler
  - building services plumbing against building services electrical, building services sprinkler
  - building services electrical against building services sprinkler.

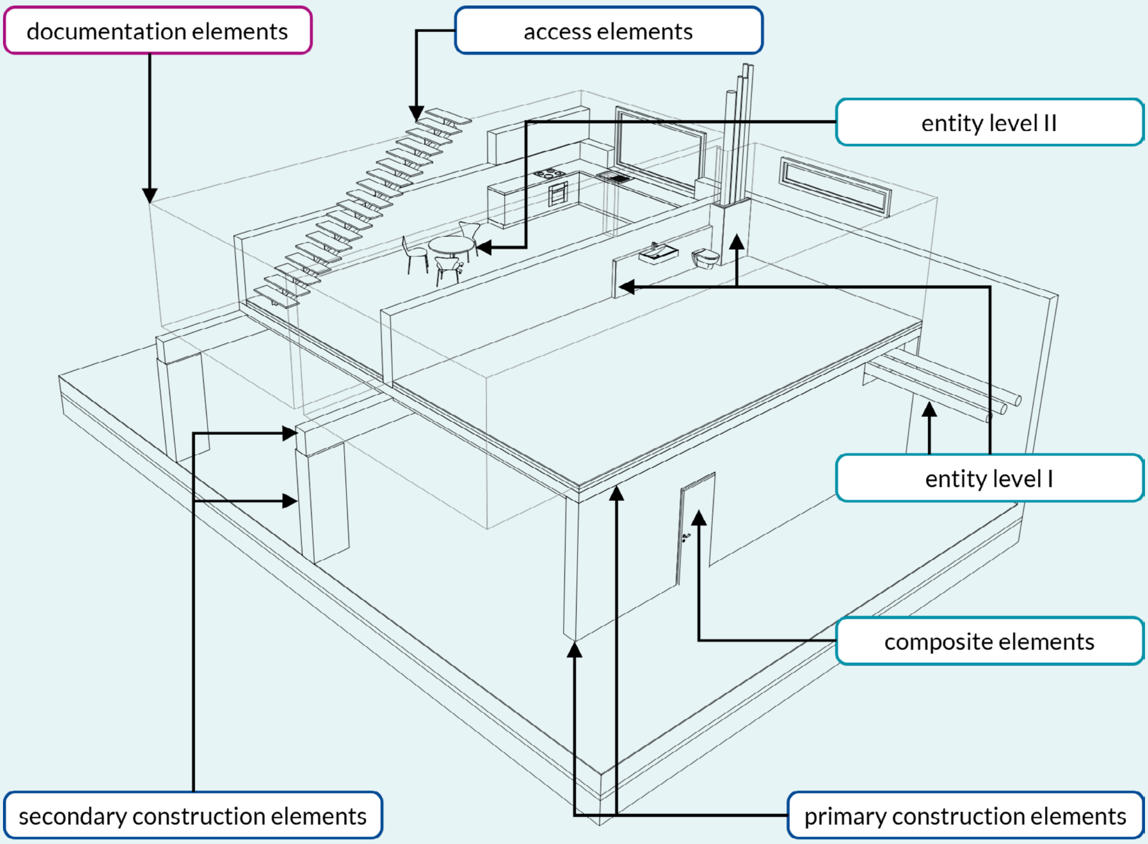
To ensure no element is overlooked, it is advisable to create a matrix of the various cross-checks.

To ensure that the individual checks within the checking criteria are always carried out in an organised and equivalent manner, elements are grouped together. These element classes should be logically grouped and labelled easy to understand. In this way, all checking criteria can be supported during the checking execution by filtering the existing elements into this element class. In checking software (such as Solibri Office), these can be stored in »classifications«.

Check report
A corresponding check report is submitted by the checking BIM role for each check performed (see Section 4.3.5). Together with the domain model, the *BIM Domain Coordination* submits a check report (.pdf and .bcf) to *BIM Overall Coordination* at the *overall coordination meetings* and the *coordination at a phase end/milestone*. *BIM Overall Coordination* prepares its review report for the same coordination meetings.

In addition to listing the issues found, a PDF check report should provide a good overview of the status of the checked domain models.

When creating the element classes, ÖNORM A 6241-2, Annex A (normative) can be used for the categorisation 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.
For example, a clash detection 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 stages of design. The following figure shows the different element classes:



Checking routine
A checking routine is a holistic product of the previously listed components (see Fig. 4.12). Each checking BIM role has its own checking routine. It consists of a specific sequence of checking criteria that build on each other. The checking criteria are performed by different BIM roles. Each checking criterion in turn consists of several checking queries (checking rules), the results of which should be classified (classification scheme e.g. »passed / not passed / passed with conditions«, see Section 4.3.5). In the case of an *overall coordination meeting*, the issues found are handed over to the responsible *BIM Domain Coordination* in the form of a check report as a task to be solved. In a *coordination at a phase end/milestone*, there should be no outstanding issues. If there are still open issues, the domain model concerned cannot be released for further use on the collaboration platform (by *BIM Overall Coordination*). However, it is also possible to issue a conditional release with a deadline for the issue to be resolved. In any case, the results of the check are recorded in a check report.

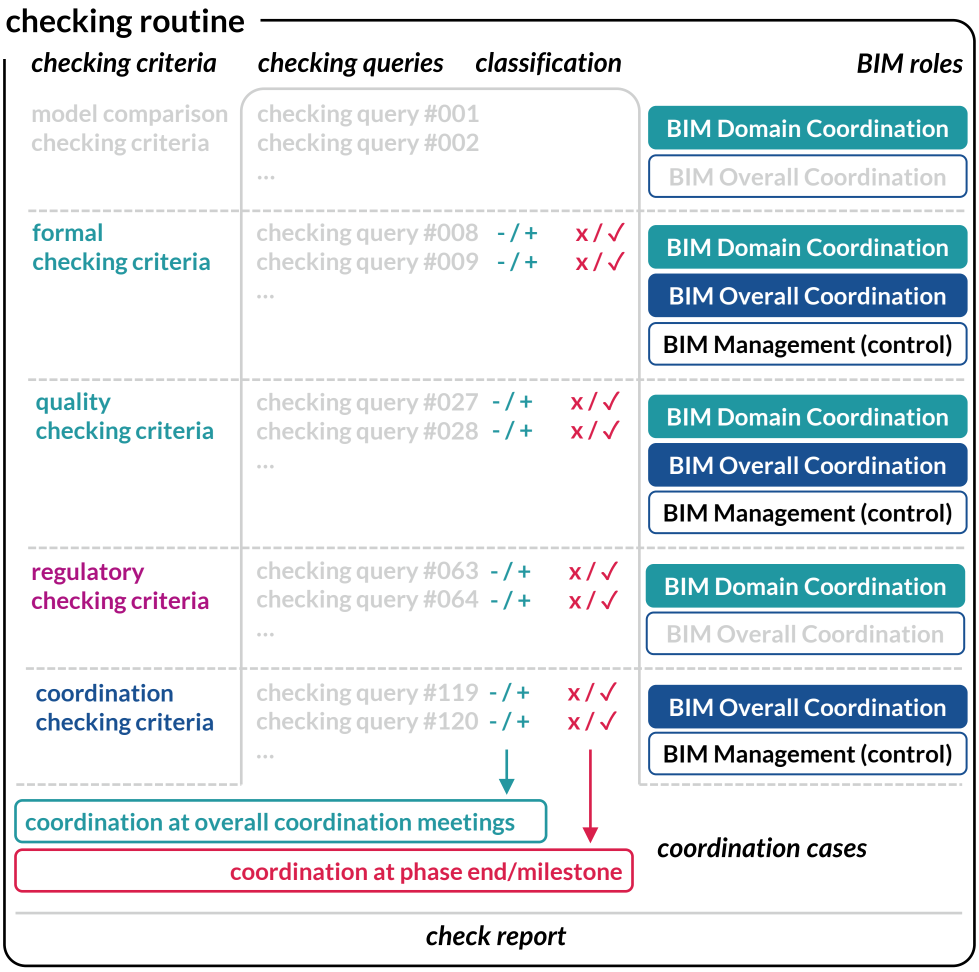


Fig. 4.12: Content of a checking routine

In Germany, VDI 2552 Part 4 distinguishes between the following check types for the quality control of coordination models:

Quality validation of partial models (sub-models) at data transfer points (*data drops*): The quality check should ensure that the discipline-specific partial models (domain models) have the required content and quality for further use.

Plausibility check: The plausibility check is often carried out using visualisations. It shows rough fitting inaccuracies in the model geometry and possibly missing geometric model content.

Visualisation: Visualisations are used to transparently represent the discipline models (domain models) and to illustrate the designs of the different specialist disciplines (domains). Not only the geometric properties of the model can be visualised, but also the results of the various simulations that were carried out based on the models.

Content validation: Content validation evaluates the geometric and attributive completeness of a model within the scope of the requirements. It also checks the qualitative characteristics of the geometry and attributes.

Clash detection: Clash detection involves geometrically checking for intersections (breakthroughs) or overlapping of bodies that are not physically possible. This can also include duplicate elements in the same location or in the same position.

Connection validation: Connection validation checks the connections between model elements. The model elements must be connected according to the design requirements. Connection tolerances must be defined in advance.

Quantity consistency validation: Quantity consistency validation compares the modelled quantities with the exported quantities. This includes both the quantities of the model elements and derived attribute values. These quantities should be checked with every model export.

4.3.5 Conducting the coordination meetings

The results of a model checking are always communicated. This is usually done in the *overall coordination meetings* defined by the *coordination plan* and the *information delivery plan* that are part of the BEP. An *overall coordination meeting* is chaired by *BIM Overall Coordination*, and the various *BIM Domain Coordinations* and the *BIM Management (control)* participate. This ensures that information regarding the design status and pending work is communicated to the *BIM Modellers* (by *BIM Domain Coordination*) and to the client (by *BIM Management (control)*).

Overall coordination meetings can also be held in combination with the design meetings, which has the advantage of ensuring a common understanding among all design participants and a focused approach to the tasks at hand (interlocking BIM topics and design topics).

An *overall coordination meeting* takes place immediately after a model check by *BIM Overall Coordination*. *BIM Overall Coordination* presents the check results within the checking software and coordinates them with the responsible *BIM Domain Coordination*. It is defined, among other things,

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

BIM Domain Coordinations can also present their internal domain model checking results in the *overall coordination meeting* and specify and agree on requirements for the other domain models. *BIM Overall Coordination* records the *overall coordination meeting* and then forwards the records, and the associated check reports to the participants via the collaboration and communication platform.

BIM Overall Coordination and *BIM Domain Coordination* check reports consist of the individual BCFs for the issues and the associated PDF check report:

- composition of the BCF check report: A check report in BCF format contains the list of check results from the BIM applications used for quality assurance. A BCF comment contains at least:
  - the GUID (*Globally Unique Identifier*) of the elements concerned,
  - a name,
  - a description,
  - stored viewpoints with an appropriate camera position on the affected issues,
  - a status indication (e.g. open, resolved, closed), and
  - assignment of responsibility to the BIM role, and
- composition of the PDF check report: In addition to listing the check results, a PDF check report provides a good overview of the status of the checked domain models. It also includes the categorisation scheme for the check results.

The classification scheme of *BIM Overall Coordination* supports the classification of the check results in the current stage of development. This makes it possible to show to all participants and the client to what extant 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 is not yet available in a sufficient form.

If the model data (as a whole or in relation to individual domain models) is not yet available in an appropriate form, *BIM Overall Coordination* can decide whether this issue can be dealt with in the next coordination meeting or whether certain deficiencies must be rectified before proceeding. This procedure applies to coordination at *overall coordination meetings* within a phase.

For a *coordination at a phase end/milestone,* however, quality gates are used as a benchmark for passing to the next phase. The model data can only be passed to the next design step if the quality gates have been passed in full or if binding conditions have been met for the elimination of defects.

Achieving a quality gate does not necessarily mean passing all checks 100% of the time. For example, a completely (100%) collision-free overall model or individual domain models can usually only be achieved with great effort. Minor collisions can be accepted if they result in:

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

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

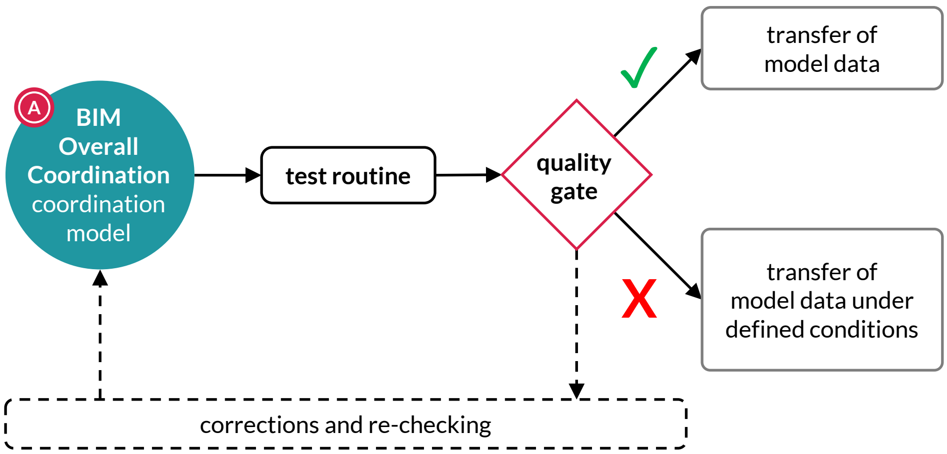


Fig. 4.13: Checking process

A classification is defined in the BEP, which checking query must be passed 100% or with correspondingly lower percentage for a quality gate.

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:

- *BIM Management (control)*:
  CDE has been set up, and the BIM roles have been trained or given access.
- *BIM Overall Coordination:*
  BEP contains all the necessary specifications (*coordination plan*).

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

- check their own domain model in the checking software,
- preparation of the check report (.bcf and .pdf), and
- timely deliver the checked domain model, the check reports, and, if required, the design documents derived from the domain model to the CDE. Informing *BIM Overall Coordination* about the delivery.

BIM Overall Coordination now has access to all relevant data and can perform interdisciplinary coordination for the coordination meeting:

- Collect the domain models from the CDE and merge them into the coordination model in the checking software (there as a native checking software format). *Note*: If this is not the first coordination meeting, the models will be updated in the coordination model.
- Check each domain model for conformity (correct positioning).
- Run the checking routines. The check must be performed for each domain model and then the domain models are checked against each other (interdisciplinary).
- Part of the check is the review of the results and the creation of issues for the problems identified, including the assignment of responsibilities and priorities.

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

- *BIM Overall Coordination*:
  Chair the coordination meeting and present the results. Depending on the scope of the issues, *BIM Overall Coordination* can address all issues or limit itself to the most urgent ones. However, all issues are communicated afterwards.
- *BIM Domain Coordination*:
  Opportunity to comment directly on issues. If issues raised by *BIM Overall Coordination* have already been solved according to the responsible *BIM Domain Coordination*, the issue still remains until it can be verified in the next coordination meeting.
- *BIM Overall Coordination*:
  The allocation of responsibilities or priorities already made can be jointly adjusted.
- *BIM Overall Coordination*:
  Conclusion of the coordination meeting and subsequent delivery of the check report (.bcf and .pdf). Reporting to the *BIM Management (control)*.

The coordination meeting is the heart of integral collaboration. All relevant BIM roles participate and contribute. In some cases, new information may arise during the project that requires an adaptation of the BEP. This is done by *BIM Overall Coordination* and must be approved by *BIM Management (control)*.

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

- Why do both architectural elements and structural engineering elements carry the property information for load-bearing elements (LoadBearing is true/false)?
  - To compare the architecture domain model with that of structural engineering (model comparison check), the architecture domain model must be reduced to the load-bearing elements in the check. Non-load-bearing elements of the architecture domain model are not considered in the comparison.
  - The architecture team must provide the structural engineering team with a separate, reduced domain model for collaboration, containing only the load-bearing elements. Model elements that are not load-bearing or documentation elements (rooms = IfcSpace) are not relevant for the structural engineering design and its work to be performed. In the modelling review, an independent transfer configuration is defined for this purpose.
- What must be considered when validating the model in different phases?
  - As the phases progress, the sharpness of the clash detection should be adjusted. This means that the tolerance values for overlaps are readjusted in the checking rules with each new phase. For example, the overlap of primary components (see Section 4.3.4) may be checked with a tolerance of 2.0 cm in the design and 0.5 cm in the permission phase.
  - Care sshould be taken that only model elements that are relevant in the phase are checked. In the design phase, it makes sense to check building services elements against architectural elements, e.g. against the load-bearing architectural elements (primary building elements), but not against finishing elements (= element class 1). It also makes sense to restrict the building services elements to the piping/cable routing and central units. The rooms (spaces) of the architecture domain model are checked against the model elements of building services at each stage to ensure the minimum clear-

ances. It would be premature to check any modelled outlets (IfcOutlet) at the design phase, as the architectural elements (e.g. walls, suspended ceilings) may still change.

- Who is responsible for interdisciplinary issues?
    - If the clash detection between the architecture domain model and the building services domain model reveals deficiencies (= clashes), *BIM Overall Coordination* must ensure that a logical coordination sequence is specified. For example, if 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 acceptable for the architecture team, the construction details are approved, and the openings are incorporated into the architecture domain model. As a result, the previously identified collisions should no longer exist at the next coordination meeting. In the case of openings, it should also be mentioned that these must, of course, also be checked, approved, and incorporated by the structural engineering team. *BIM Overall Coordination* assigns such issues to the building services team as the responsible body, but the architecture team and the structural engineering team are also listed in the BCF commentary for information purposes.

4.3.6 Performing the information delivery

Information delivery (data transfer) is a use case that occurs at a phase end/milestone. It concerns the final design results of a phase that need to be transferred. These are to be delivered by the respective *BIM Domain Coordination* on the collaboration and communication platform. The naming specification and scope specifications as defined in the BEP apply to all appointed parties.

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

- Compliance with the specification for the level of detail of the domain models.
- Compliance with these requirements must be ensured before the data is made available on the collaboration platform; authorization is given by *BIM Overall Coordination*:
    - All aspects to be checked must provide positive results; this is to be understood as a corresponding quality gate.
    - Any further review of the content of the functional project objectives must be carried out separately.
    - Compliance with the requirements must be demonstrated by means of an attached check report according to the specifications.
- Supplementary information or more detailed information (e.g. detailed drawings) are placed in the domain model by the *BIM Modeller* using BCF comments.
- All design documents are derived from the relevant domain model.

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

- In accordance with regulative specifications.
- Drawings (DWG/DXF files) must correspond to the checked and approved status of the domain model (IFC file). 2D information contained only in the drawings (e.g. dimensions) must not contradict the information in the domain model.

For the transfer of drawings (PDF file), the following applies:

- Drawings (PDF files) must correspond to the checked and approved status of the domain model (IFC file). 2D information contained only in the drawings (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, including any extensions or program add-ons, and a list of all additional special elements (for domain models as IFC files and for drawings as DWG/DXF files) must be provided.

4.3.7 Performing the model-based cost calculation

Performing model-based cost calculation is a use case that is encountered at various phases.

Requirements

The cost calculation is carried out in an evaluation software. Domain model data are used which have previously been checked and authorized by *BIM Overall Coordination* for the purpose of quantity and mass determination on the collaboration platform (status: *authorized*):

- *Requirement*: domain model authorized according to quality gate.

Depending on the coordination between *BIM Overall Coordination* and the team carrying out the cost calculation, different domain model data can be used. However, they are always based on the LOG and LOI specifications and the base quantities (BaseQuantities) transported in an IFC model.

- *Requirement*: plausibility checks before and after the cost calculation.

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

- *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 the ability to handle multiple IFC models. The results of the quantity and mass calculation are then used, e.g. in the cost calculation items for a tender.

Implementation

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

- The released domain models (IFC file) serve as the basis for the data collection.
- The identification of the model content shall be based on the declared IFC classes, IFC types, material assignments, and standard properties.
- Masses and quantities must be derived from the model geometry.

4.3.8 Updating the project specifications during design

The BEP is a living document. It is created at the beginning of the project, based on the specifications and requirements of the project-related *Client's EIR*. However, to remain applicable for a project throughout its life, the BEP must be able to respond to developments in the project and constantly evolve.

BIM Overall Coordination is responsible for updating the BEP. Changes in the BEP must always be coordinated with *BIM Management (control)* to continue to fulfill the client's specifications and requirements.

Updates to the BEP may be based on

- Updates to the BEP may be based on
- extended requirements from the client,
- extended requirements from the contractors,
- extended or adapted procedures,
- expanded knowledge, and
- changed specifications for
    - the project participants,
    - the formats,
    - the transfer configurations, and
    - the use cases.

Adjustments to the BEP must also always be communicated to the project-related *Client's EIR*, although an update of the *Client's EIR* by the *BIM Management (client)* is not mandatory. However, new knowledge gained during the project should be examined to determine whether they should be incorporated into the project-independent company standard EIR, so that the new knowledge can be considered in future projects. It is the task of *BIM Management (client)* (supported by the *BIM Management (control)*) to maintain the project-independent company standard EIR.

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,
- formats,
- codes, standards, and regulations,
- authorship and responsibility of the domain model content,
- mandatory coordination with other domain models,
- internal quality assurance,
- transfer configurations,
- modelling, and
- degree of completion.

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

4.3.10 Model-based building permission process

The *openBIM* model as the central location for building data and information has potential for the entire lifecycle of a building. However, building submission, building application, or building permission currently play little role in the BIM project cycle. Rather, the current submission documents represent additional work for BIM designers, as conventional 2D drawings must be generated from the models and enriched in a specified manner. This is a massive media disruption.

An *openBIM* permission process offers a wide range of advantages not only for the authorities, but also for the entire construction industry. These are primarily seen in increased transparency in the implementation of the process and increased comprehensibility of the decisions. A detailed analysis reveals the following benefits:

- The elimination of time-consuming routine inspections by the building authorities means that the capacity freed up can be concentrated on the more legally complex inspection points. This accelerates and improves the quality of the permission 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 small and medium-sized design firms, which can rely on their modelling software rather than having to purchase new software for new projects.
- Design offices receive an automatic, baseline quality check that can be performed at any time through a BIM check on technical specifications (even before a building application is submitted). This reduces red tape, improves the quality of the submitted model, and accelerates the design application process as a result. In practice, design offices could also use the check for staff training purposes.
- The building authority process becomes more transparent.
- The biggest benefit for the construction industry lies in the LOG and LOI requirements: Usually, the project's *Exchange Information Requirements* (EIR) and the associated LOG and LOI requirements vary widely. An *openBIM* permission process creates a common standard across projects – a kind of quality seal – as the permitted BIM model must meet clear LOG and LOI requirements. The building applicant (client) and downstream companies (e.g. contractors for costing) can hence better implement the BIM model in their BIM applications, as the information is already stored and checked in a standardised way.

An *openBIM* permission process will therefore make a significant contribution to making better and more far-reaching use of the advantages of BIM and to support more design offices before and during the building application process. Building authorities and administrations alike will benefit from the standards required for *openBIM* submissions. This takes BIM design to a new level and adds an important aspect to the use of BIM.

As a result of these benefits, more and more projects are now addressing the issue of digital transformation of the building authorities or the permission process. The city of Vienna, Austria, e.g. has developed a platform for »digital building submission«. Building applicants/planners can access this platform, narrow down the types of processes, and upload submission documents. As part of the EU-funded BRISE-Vienna research project, the city of Vienna has gone one step further and aims to integrate the permission process into the entire BIM project cycle.

Based on the research projects »Digital Building Submission« and »BRISE-Vienna«, the maturity model for permission processes shown in Fig. 4.14 was developed according to ISO 19650. Municipalities' maturity level ranges from Level 0 to Level 3. The current starting point for many local authorities is Level 0. Submission/application documents are submitted in printed form and manually viewed, entered in a digital platform, and checked by the relevant expert. Communication takes place via e-mail or by letter. Achieving Level 1 requires an actual process analysis followed by a target process evaluation. This actual/target process evaluation defines the necessary technical (collaboration web platform) and legal developments. This step is crucial, as it does not make sense to simply digitise existing processes. The use of new digital tools (BIM, drones, AI, AR, etc.) in public authority processes 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. 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 Level 3, the permitted development is then displayed in 3D, which means that considerably more neighbourhood law issues can be checked automatically. In Level 3, the completion notifications are also model-based, giving the authority a digital twin of its municipality over time. The final step is the integration of the current building logbook, in which all maintenance intervals and condition assessments of relevant components are documented according to the Vienna Building Code into the BIM model.

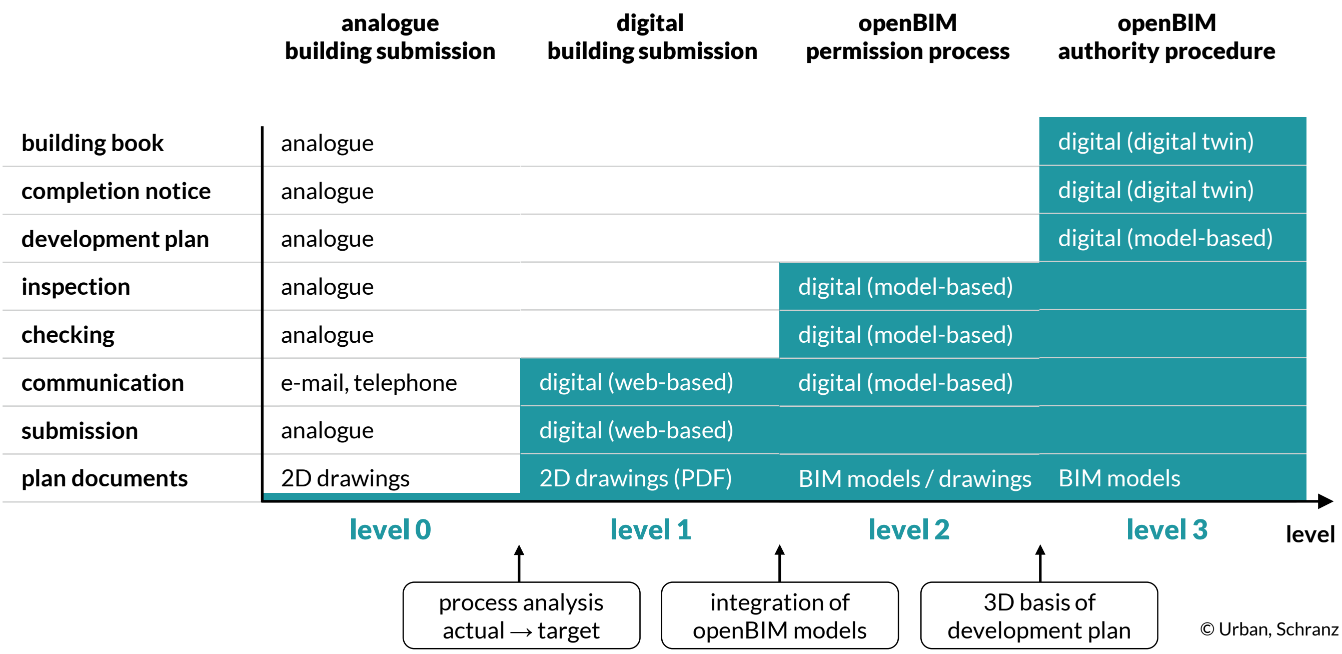


Fig. 4.14: Digital maturity stages of the (public) building authority process

4.3.11 Performing the test run of the connection to the operator's CAFM system

For many FM departments, setting up operations management – especially based on model-based information from BIM projects – is a new situation that requires intensive preparation. For this reason, a test run is often carried out during the project to connect the CAFM system of the future operator. This takes place at the latest at the end of the design phase, when fully coordinated and sufficiently detailed model content is available for the first time. The asset information model (AIM, according to ISO 19650) is used to transfer the model to operational management.

It is necessary to adjust the intended scope of the information delivery in the *information delivery plan* during the creation of the BEP (see Section 4.2.8). Various specifications are brought forward, which are normally only to be provided with the final documentation. Such specifications include various tabular model evaluations that transfer model content to the CAFM system. In addition, the transfer of supplementary documentation and its link with the model content is tested.

The aim of the CAFM connection test run is to prepare the operators and their CAFM systems at an early stage. If problems are identified during the test run, there is time to resolve them. Any problems with the model content or its specification in the BEP can also be resolved at this stage.

The test run for the connection of the CAFM system is carried out under the direction of the *BIM Management (control)*, which manages the activities of *BIM Overall Coordination* and their respective *BIM Domain Coordination* and liaises with the FM department of the operator.

4.4 Procurement – tendering and awarding

The »Procurement« phase is used to identify and appoint a contractor to carry out the construction work (*Construction Contractor*). This is based on the principles developed in the previous »Design« phase.

Phases (P):
ÖNORM A 6241-2: »Design« P 2; »Tendering and awarding« P 2.6 & 3.0
HOAI: »Design« P 2 bis 5; »Prepare of contracted award« P 6; »Assisting award process« P 7
SIA 112: »Project Planning« P 3; »Tendering Phase« P 4

At this phase only the procurement process is carried out. BIM model data can be used to support procurement (calculation of masses and quantities, clarification of the design intent). However, they are only a supplement to the actual core component of the tender: the service description. The following use cases describe a currently (2024) common scenario for BIM-supported tendering and awarding. In this scenario the *Design Contractor* already determines the masses and quantities of the predominant service items based on the domain models. Some areas of the service description are still handled conventionally because they are not included in the domain models (e.g. vapour barriers, edge insulation strips). In addition, the collaboration platform can serve as a basis for processing the procedure, and model data is made available to the bidders for review. The phase concludes with the appointment of a *Construction Contractor* and a jointly agreed BEP with defined BIM-processes. Depending on the BIM skills of the *Construction Contractor*, the procurement of services may take different forms (see Section 4.4.4) and needs to be considered during this process.

When determining the masses and quantities of the service items, it must be agreed to consider any contract to provide services (works contract). In Austria, according to the ÖNORM A 6241-2, these can also be disregarded at the client's request and net-quantities can be used instead. In Germany, depending on the client, the principles of public procurement law must be observed and not circumvented.

4.4.1 Assessment and need/requirement

The client (appointing party) or *BIM Management (client)* and the responsible *Design Contractor* identify the project-related requirements for the award of the construction contract. The corresponding planned information delivery from the prospected *Construction Contractor* to the *Design Contractor* is also determined and the information requirements for the project are defined. Any company-wide, cross-project specifications (such as the *Client's EIR*) serve as the basis for the requirements assessment. As part of the invitation to tender, the *Client's EIR* describes the requirements for structured information delivery by the *Construction Contractor* during the construction phase, depending on the information delivery strategy. Clients with in-house BIM project expertise use the client's pre-defined company-wide OIR, PIR, and AIR, or the client's cross-project EIR. These documents define the general framework for basic uniform process implementation and information delivery (e.g. of product information from the *Construction Contractor* to the *Design Contractor* as an essential part of the construction documentation) across all projects.

In the *first step*, the *Design Contractor* and the client (appointing party) or *BIM Management (client)* determines the most suitable tendering and procurement strategy for the project. The project complexity and size, the assessment of capabilities of the potential bidders, and the corresponding objectives of the client are decisive criteria. In the second step, the client or *BIM Management (client)* summarises these requirements on a project-specific basis. Thus, they are available as a basis for the subsequent compilation of the *Client's EIR*.

The *Client's EIR* provides bidders (prospected appointed parties) with an overview of

- the overall project-related BIM processing,
- the information delivery strategy used,
- their tasks related to this,
- the resulting responsibilities during construction,
- the platform used for information delivery and tendering process,
- the client's information requirements in terms of organisational, process, and information specifications,
- the intended use of the information during the operational phase,
- the required LOIN and the structure of the construction documentation,
- the acceptance criteria for each information requirement (project information standards, project-related information generation methods and procedures, use of reference information or shared resources),
- supporting information (project information, documents and guidelines, references to applicable standards), and
- dates related to the milestones.

This enables the bidders to precisely estimate the required effort to participate in the BIM project and include this in their bid. It also enables the bidders to assess and subsequently verify the BIM capability of any additional subcontractors required.

The *Design Contractor* compiles the reference information and shared resources to be made available to the bidders (prospected lead appointed parties) during the tender process. These are the service description, the planning documents derived from the digital models (construction and detailed planning), and the project-specific basis models. The specific basis models are used:

- as an appendix to the tender (clarification of the design intention),
- as a basis for the model-based preparation of alternative service proposals by the bidder, and
- as a basis for the model-based completion of the relevant sections of the service description.

The compiled documents are usually made available in the project's CDE. *BIM Management (control)* is usually responsible for the collaboration platform and must therefore set up access for the bidders. The CDE should be set up prior to the tender to allow secure information exchange between the participating organisational units for the tender processes. For the tender and award process, the following requirements must be prepared:

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

The result is a collaboration platform that is set up in accordance with the corresponding specification of the BEP for the tender processes. The range of functions required for 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.

4.4.2 Preparing and performing the tender

In a BIM-supported tendering and awarding, the *Design Contractor* prepares a tender package with all documents in consultation with the client or *BIM Management (client)*. The following work steps are relevant:

- final determination of the masses and quantities for the most important service items from the checked and approved/authorized domain models by *BIM Domain Coordination* as well as by *BIM Overall Coordination* in accordance with the specifications of the BEP,
- final reconciliation of the *Client's EIR* (of the appointing party) to describe the requirements of a structured information delivery during construction,
- timely coordination and definition of the information delivery strategy with the client (as-built documentation by *Design* or *Construction 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.

In addition to the traditional tendering process, the following should be considered when tendering and awarding using BIM:

- determination of *exchange information requirements*,
- information on shared reference information and resources (e.g. collaboration platform, procurement platforms, libraries, construction documentation specifications, etc.),
- establish the master *information delivery plan*,
- methods and procedures for generating project information, and
- the criteria for the best bidder aspects (optional).

The results are finalised, coordinated documents for the tender, in accordance with the relevant specifications of the BEP. To determine the best bidder for the construction work, the following steps are taken:

1. announcement of the compiled invitation of tender and summoning of intended bidders, if any,
2. bidders register their interest and get access to the collaboration platform (or separate procurement platforms),
3. bidders receive all relevant tender documents on the collaboration platform (or separate procurement platforms) – in particular:
    a. service description,
    b. the relevant domain models (ideally barrier-free by means of integrated viewer functionality and a visualised link to the service description),
    c. the execution plan and detailed plans derived from the digital model and
    d. the *Client's EIR* to describe the general project-related handling of BIM, the related tasks of the *Construction Contractor*, and his responsibilities during construction.

In Austria, there are standard service descriptions for building construction, building services resp. transport and infrastructure. These documents are structured according to the ÖNORM A 2063-1. The document ÖNORM A 2063-2 now aims to create a common database between IFC and procurement (using so-called procurement elements). The BIM project element lists using these so-called procurement elements are linked to a standardised service description (e.g. LB Hochbau).

In Germany, tenders are generally standardised and VOB-compliant according to STLB-Bau.

4.4.3 Tendering proposal / bid

The bidders (potential lead appointed party) prepare a bid for the tendered services within the specified deadline and post the bid on the collaboration platform. The following activities must be carried out:

- Nominating a responsible and competent individual (within its own BIM organisational units) to undertake the information management function in accordance with the *Client's EIR*. Alternatively, the bidder may assign this role to subcontractors (task team). But it is mandatory to provide evidence of the exact scope of services and their competences to the *Design Contractor* and *BIM Management (control)* or the client.
- Define the (pre-appointment) BEP of the information delivery team – as a formal implementation proposal – with announcement of the following issues:
  - qualifications,
  - information delivery strategy,
  - federation strategy,
  - responsibility matrix of the BIM organisational units (roles),
  - development of additions or changes to project information generation process, and
  - list of the software, hardware, and IT infrastructure to be used.
- Aggregating the assessments of the capability and capacity of the *Construction Contractor*.
- Establish a mobilization plan for *Construction Contractor*s.
- Create the *Construction Contractor* delivery team's risk register.

Finally, the offer of the *Construction Contractor*'s delivery team is drawn up. This should include:

- bid according to the service description,
- (pre-appointment) BEP of the information delivery team,
- capability and capacity assessment summary,
- mobilisation plan, and
- information delivery risk assessment.

4.4.4 Awarding (procurement) / appointing party

The *Design Contractor* analyses the bids on the collaboration platform and creates a price comparison list for the qualified comparison of the bidder data in close consultation with the client or *BIM Management (client)*. This serves as a basis for preparing the negotiations. The following work steps are relevant in the BIM-enabled procurement scenario:

1. *BIM Management (control)* reviews and advises the client or *BIM Management (client)* on the pre-appointment BEP of each bidder.
2. *BIM Management (control)* determines the BIM capability of each bidder and prepares a summary for the client or *BIM Management (client)*.
3. The client or *BIM Management (client)* determines or adapts the information delivery strategy for the construction based on the results of the previous two points.
4. Negotiations or renegotiations are conducted with the best bidder or second-/third-ranked bidders. Any rework of the bids is handled, reviewed, and analysed on the collaboration platform.
5. The contract is awarded or, after unsuccessful negotiations, the invitation to tender is amended with changed criteria or other required services.

The best bidder criteria consider project-related aspects, the current market situation, and the BIM performance of the BIM organisational units (roles).

Information delivery strategy

Already in the »tendering« phase, the client, *BIM Management (client)*, and *BIM Management (control)* need to develop an information delivery strategy for the as-built documentation and the governmental verification. They document the results in the *Client's EIR*. The following information delivery strategy for as-built documentation / governmental verification can be used:

- Information delivery through the *Design Contractor* or
- Information delivery through the *Construction Contractor*.

Depending on the information delivery strategy chosen, the next steps and procedures for appointing parties will vary. Furthermore, the contractual situation between the client and the *Design Contractor* or *Construction Contractor* influence choice of the information delivery strategy.

Information delivery through the Design Contractor

In this strategy, the *Design Contractor* is commissioned to provide the as-built documentation or the governmental verification for the project and follows the construction as part of the Site Supervision.

As the *Design Contractor* continues to develop the digital models, this information delivery strategy allows to commission *Construction Contractor*s with little or no BIM capability. The responsibility matrix and the definition of roles in the BIM organisational structure of the *Design Contractor* remain unchanged after the design phase. The previous BIM roles (of the planning phase) and *BIM Overall Coordination* must be contracted by the client with the services »Monitoring of construction execution« including the optional services »Updating of documents«.

Once appointed, *BIM Management (client)* and *BIM Management (control)* discuss the project strategy with the *Construction Contractor* within the scope of the *Client's EIR* to establish a common view of the project requirements and processes. The BIM organisational units (roles) responsible for the project throughout the entire execution phase are informed of all the developed specifications (e.g. BIM implementation documents, guidelines, service specifications, workflows, quality assurance, responsibilities, milestones, objectives).

After the project presentation, *BIM Management (client)*, *BIM Management (control)*, *Design Contractor* and *Construction Contractor*s clarify the project requirements and processes during the BEP review meeting. *BIM Management (control)* moderates this activity. The results are updated in the BEP by *BIM Overall Coordination* of the *Design Contractor* and thus form the mutually agreed procedure for the construction. The result of the BEP review meeting is a confirmed and updated BEP with a current and detailed responsibility matrix and more precise use case descriptions.

However, mixed strategies can also be used to determine the authorship of the domain models. For example, the architecture domain model may remain with *BIM Domain Coordination* of architecture (*Design Contractor*), while the building services domain model passes to the *Construction Contractor*. However, the effort required to transfer the model must be considered. The associated change in model management or any change in the BIM authoring software can be time consuming and wasteful. Decisions to this effect must always compare the total costs with the achievable value. As a rule: short-term savings in construction costs must not cancel out long-term savings in operation determined during the design phase.

Information delivery through the Construction Contractor
This information delivery strategy shifts the authorship of the digital domain models and the role of *BIM Overall Coordination* to the *Construction Contractor*. Further coordination and checking of the domain models during assembly and work planning (*A+W planning*) – in particular in the event of changes and deviations – is carried out by *BIM Overall Coordination* of the *Construction Contractor*. The approval for the execution of the *A+W planning* is given by the responsible *BIM Domain Coordination* of the *Design Contractor* in consultation with *BIM Management (control)* and the client.

Once the contract has been awarded, *BIM Management (client)* and *BIM Management (control)* develop the project strategy and the EIR with the *Construction Contractor*. *BIM Management (client)* and *BIM Management (control)* provide the full scope of the developed principles (BIM implementation documents, service specifications, *Client's EIR*) to the commissioned *Construction Contractor* and explain the details. This step is necessary to clarify all interrelationships and requirements by mutual agreement, and to establish a consistent view of the project requirements for implementation by the entire project team. The *Construction Contractor* will also provide the responsible persons for the information delivery and the required BIM roles.

Subsequently the BIM review meeting takes place. In this BIM review meeting, the *Construction Contractor* specifies how, and in which steps the client's specifications (from the *Client's EIR*) will be implemented. *BIM Management (control)* moderates this process; the *Construction Contractor* provides the relevant content. The results flow into the updated BEP (by *BIM Overall Coordination*). This results in a mutually agreed procedure laid down in the BEP by *BIM Overall Coordination* (of *Construction Contractor*). This is aligned with the actual capabilities of the staff of the *Construction Contractor* working on the project, as well as their BIM software applications. This runs within the framework of the general specification – the pre-defined company-wide OIR, PIR, and AIR, or cross-project *Client's EIR*.

Due to the transfer of authorship for the domain models from the *Design Contractor* to the *Construction Contractor*, the regulation of the PIM is essential. For this reason, the modelling review meeting takes place afterwards (chaired by *BIM Management (control)*). It is used to evaluate the specifications for model-based project implementation in accordance with the BEP of the appointed party. It shall ensure that the *Construction Contractor* can perform the intended model update tasks with the intended BIM software applications in the required quality. The *Construction Contractor* must be able to demonstrate the successful completion of relevant use cases and implementation of the specifications in the BEP using a section of a model. This includes the native transfer of the model data into the contractor's own BIM authoring software and ensuring that it can be further processed. These steps must be completed prior the start of construction to ensure the full feasibility for the *Construction Contractor*.

Once the methods and procedures for generating information have been successfully tested, the *Construction Contractor* is able to participate in the BIM project starting from the construction preparation or the *A+W planning* through the entire construction process until the handover. The *Construction Contractor* can thus continue to use and update existing BIM information and provide the required information in a structured manner on this basis. The entire project team can collaborate across design and construction without media disruption.

Based on the BEP, the *Construction Contractor* must prepare the *Exchange Information Requirements* for each appointed party (sub-organisational unit) so that the information requirements, the required depth of information, the required quality, and the agreed milestones are met. In addition, the *Construction Contractor* must prepare a *task information delivery plan (TIDP)* with all subcontractors, consolidate it into a *master information delivery plan (MIDP),* and make it available to *BIM Management (control)*. The *master information delivery plan (MIDP)* is also managed through change control throughout the construction phase.

Appointed parties are, for example, subcontractors or suppliers of building materials or building products who provide digital product information (in accordance with ISO 23386).

4.5 Construction

The »Construction« phase is used for the realisation of the project by the *Construction Contractor* selected in the previous phase. This is based on the fundamentals developed in the »Design« phase.

Phases (P):
ÖNORM A 6241-2: »Constructioin« P 4
HOAI: »Assisting award process« P 7; »Project supervision« P 8
SIA 112: »Implementation« P 5

4.5.1 Performing the model-based construction scheduling

The implementation of 4D BIM design (usually) focus mainly on the documentation of the project and serves to map the construction process that is planned or 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. Depending on the information delivery strategy used, the properties are either updated by the *Design Contractor* using the information provided by the *Construction Contractor* or by the *Construction Contractor* itself. If the domain models are used for interim invoicing of trades, they must be verified by the **digital local site supervision** to ensure that they match the actual status.

To perform 4D BIM design, a model structure is required that corresponds to the cycles of the construction process – e.g. concreting sections.

Requirement

Model-based construction scheduling is carried out based on the following rules:

- Access to the collaboration platform must be provided for the *Construction Contractor* and the *local site supervision*. If information delivery is appointed to the *Design Contractor*, access is also required for the *Design Contractor*.
- All changes and deviations must be updated in the respective domain model by the responsible BIM roles.
- Delivery of the updated and checked domain models by the responsible BIM roles on the collaboration platform.
- *Construction Contractor* provides the construction schedules.

Realisation

- Linking the domain models to the construction schedule by the responsible BIM roles and
- verification of construction progress by *local site supervision*.

Result

- Visual representation of the model-based construction schedule,
- visual representation of the model-based construction progress, and
- verified interim invoicing for trades.

4.5.2 Performing the assembly and work planning (A+W planning)

The *Construction Contractor* carries out the *A+W planning* which serves as the basis for the manufacture of components and building elements. The *Construction Contractor* coordinates the use of the intended building products in accordance with the specifications by the *Design Contractor*. The *A+W planning* is always carried out using domain models and 2D-based detailed drawings. The *A+W planning* describes in detail how the construction is to be carried out with the intended building products for all trades of the *Construction Contractor*. The interaction between the fully coordinated and optimised domain model of the *Design Contractor* and the *A+W planning* of the *Construction Contractor* is defined in the BEP depending on the information delivery strategy.

If the as-built documentation is delivered by the *Design Contractor*, the authorship for maintaining the domain models remains with the responsible *BIM Domain Coordination* of the *Design Contractor*. Ideally, the *Construction Contractor* provides the *Design Contractor* with the *A+W planning* in the form of domain models or, alternatively, as 2D drawings. The documents provided are viewed by the responsible *BIM Domain Coordination* of the *Design Contractor* and transferred into the domain model. The information model is then checked internally in accordance with the methods and procedures for information generation according to the BEP. If the review is successful, the domain model is sent to *BIM Overall Coordination* (in the domain of the *Design Contractor*) for coordination and review with the coordination model. Once approved and authorized by *BIM Domain Coordination* and *BIM Overall Coordination*, respectively, *BIM Management (control)* must give the final approval for execution in consultation with the client.

If the information delivery of the as-built documentation is carried out by the *Construction Contractor*, each appointed party (sub-organisational unit) creates a domain model for *A+W planning* in accordance with the defined **task information delivery plan TIDP**. In addition to the domain models, conventional 2D detail drawings are produced and linked in the digital model for better understanding. The author of the *A+W planning* performs a quality assurance check of the digital model in accordance with the BEP before delivering the documents. If the check is successful, the domain model is made available on the collaboration platform for review and approval by *BIM Overall Coordination* of the *Construction Contractor*. Once the *A+W planning* domain models have been successfully checked with the framework of the federated coordination model by *BIM Overall Coordination* of the *Construction Contractor*, they are evaluated, approved and authorized by the responsible *BIM Domain Coordination* of the *Design Contractor*. The final approval for execution is given by the client if the review is positive.

In general, it must be ensured in advanced that the framework specifications of the design model are (essentially) not exceeded in the *A+W planning*. This is done during the tendering and awarding process by means of appropriately formulated restrictions in the tender documents. The fully coordinated and optimised quality of the *Design Contractor* domain model must be maintained. If changes on the part of the *Construction Contractor* lead to rescheduling, it must be ensured that overall added value is generated. The effort required to update the model must also be considered.

The 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 *Design Contractor* shall be made available on the collaboration platform,
- the detailed design performed by the *Design Contractor* shall be linked to the respective construction elements of the digital models (by means of BCF comments or a BCF file),
- the *Construction Contractor* shall deliver the relevant documents of the *A+W planning* in digital form on the collaboration platform, and
- approval of the *A+W planning* in digital form on the collaboration platform by the responsible *BIM Domain Coordination* of the *Design Contractor* as well as *BIM Management (control)* or the client.

In addition, the following applies to the as-built documentation delivery strategy by *Design Contractors*:
- If a revision of the digital models of the *Design Contractor* is made necessary due to incorrect or incomplete information delivered by the *Construction Contractor*, the respective expenses of the *Design Contractor* shall be recorded (for each 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 responsible *BIM Domain Coordination* of the *Design Contractor* to be inserted into the digital models after approval by *BIM Management (control)*. The changes are to be transmitted regularly, with the transfer intervals to be determined jointly by the *Design Contractor* and the *local site supervision*. In any case, the changes must be transmitted model-based using BCF comments or a BCF file.

Implementation
The following specifications apply to the execution of assembly and work planning:
- The *Design Contractor* provides execution and detailed design information (consisting of digital models, drawings, details) on the collaboration platform.
- Based on this information, the *Construction Contractor* carries out the conventional *A+W planning* (digital models including the corresponding execution details, selection of products, etc.) with including documents.
- The *Construction Contractor* provides the *A+W planning* (digital models and associated documents) on the collaboration platform.
- The *Construction Contractor* links the detailed planning information (from *A+W planning*) on the collaboration platform with the digital models of the *Design Contractor* by means of BCF comments or a BCF file.
- The responsible *BIM Domain Coordination* of the *Design Contractor* compares the execution and detailed design with the *A+W planning* of the *Construction Contractor*. If deviations (position, dimension, specification) are identified, effects on the existing design data must be checked by the *Design Contractor*.
- The *Design Contractor* coordinates with the *local site supervision* and *BIM Management (control)* on how to proceed with any changes. If necessary, the *Construction Contractor* modifies the *A+W planning*.
- The responsible *BIM Domain Coordination* checks and approves the documents provided by the *A+W planning* of the *Construction Contractor* and informs *BIM Management (control)* and the client.
- The final approval for execution is issued by the client after successful checking.

Result

The following results are to be produced during the *A+W planning*:

- approved *A+W planning* of the *Construction Contractor*, which has been integrated into the execution and detail design of the *Design Contractor*,
- an approved *A+W planning* of the *Construction Contractor*, which can be used as the basis for construction,
- all documents of the *A+W planning* of the *Construction Contractor* 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 *Design Contractor* by BCF.

4.5.3 Performing the as-built documentation during construction

The *Surveying* team and the BIM Modellers responsible for the domain model carry out the as-built documentation during construction. Hence, they ensure that the construction conforms to the planning specifications (at the level of *A+W planning*). Laser scanners are used to record the respective construction phases. 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 domain model. The relevant specifications for implementation and the associated responsibilities are defined in the BEP. The result is the complete documentation of the as-built status in the form of updated domain models.

Requirements

Model-based as-built documentation is performed according to the following 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 status).
- The recording of the building condition (actual condition) is to be carried out by qualified staff of the *Surveying* team by means of laser scanners according to the following description.
- The *local site supervision* reports completion dates to the *Surveying* team in a timely manner.
- The *Construction 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 time of the execution are to be determined by the *local site supervision* in collaboration with the *Construction Contractor*:
    - completion of shell (storey by storey),
    - completion of MEP/collecting lines (storey by storey),
    - completion of finishing/dry wall construction (storey by storey, single-sided planked walls),
    - completion of MEP-V (storey by storey, main lines / control centres / distributors),
    - completion of MEP-E (storey by storey, main lines / control centres / distributors),
    - completion of MEP-S (storey by storey, main lines / control centres / distributors), and
    - completion of building and exterior (as a whole).

- Provision of the results of the survey is to be carried out via the collaboration platform.

Implementation
The following guidelines apply to the implementation of the as-built documentation:
- The *Construction Contractor* shall inform the *local site supervision* of upcoming completion dates.
- The *Construction Contractor* shall coordinate the dates for the recording of the construction status (actual condition) with the *local site supervision*.
- The *local site supervision* reports the surveying dates for the recording of the condition of the construction (actual condition).
- The *Construction Contractor* prepares the completed section (storey by storey) for the recording time slot and ensures visual accessibility (e.g. removal of material storage, scaffolding, etc.).
- The *Surveying* team performs the recording of the status of construction (actual condition) on the scheduled date.
- The *Surveying* team reports completion of the recording of the construction condition (actual condition) to the *Construction Contractor* and the *local site supervision*.
- The *Surveying* team provides the results to the *BIM Overall Coordination*.
- The *BIM Overall Coordination* 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 tolerances (according to the service description).
- In case of deviations, the *local site supervision*, the responsible *BIM Domain Coordination*, and *BIM Management (control)* will be notified.
- The client decides in consultation with *BIM Management (control)* or the *local site supervision*:
    - 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, drawings, if necessary, also details) by the responsible BIM Modeller of the respective domain model at the expense of the originator.

Result
The following results are to be produced during the creation of the as-built 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 status of construction by means of updates to the execution and detailed design (consisting of domain models, plans, associated final details).

4.5.4 Peforming the model-based product documentation

Depending on the information delivery strategy, either the *Design Contractor* or 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 as-built documentation serve as the basis. Based on these models, construction product specifications are collected and randomly checked for compliance with the built construction. The product specifications in the domain model are maintained by the *Design Contractor* / *Construction Contractor* in accordance with the information delivery strategy. The required product specification for operational management (maintenance, checking, warranty, etc.) are entered in the domain model and the associated documents (technical approvals, instructions, etc.) are collected in a structured manner. These documents are stored in a structured manner on the collaboration platform and linked to the domain model. The relevant specifications for implementation and the associated responsibilities are defined in the BEP.

The result is a complete product documentation of the as-built status contained in the updated domain models as well as the linked documents.

Implementation

The following guidelines apply to the implementation of the final documentation:

- *BIM Management (control)* provides templates (which may not be changed structurally by the *Construction Contractor*) for the transfer of product information. The content of the product information tables refers to elements (and their unique identifier: GUID) from the domain models.
- The *Construction Contractor* shall provide the product proposal (based on the *Design Contractor*'s template) during the *A+W planning*.
- The client / *Design Contractor* / *local site supervision* check equivalence and issue the product proposal for approval if necessary.
- The *Construction Contractor* shall send product information in structured form (based on templates for the transfer of product information provided by *BIM Management (control)*) to the *Design Contractor* (as an Excel spreadsheet or via a database interface).
- The *local site supervision* verifies products in the completed structure on a selective basis and issues approval if necessary.
- The respective responsible author transfers the product information to their domain model.

For transmission of product information, see tables in accordance with ÖNORM A 7010-6, Annex B

Result

The following results are to be produced during product documentation:

- updated domain models (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 domain model.

4.5.5 Compiling and handover of construction documentation

This activity is carried out by the responsible BIM Modellers of the domain models as soon as construction is complete. It serves to review and summarise the steps that were carried out when creating the **as-built** and product **documentation**. The relevant specifications for the implementation and the associated responsibilities are defined in the BEP.

The result is a complete, verified documentation of the as-built structure, contained in the updated domain model and technical documentation, suitable for handover to the operational management. The following applies: The handover of the final documentation for the construction handover must be complete and free of error. When the associated domain models (IFC file) are provided, additionally the following applies:

- The specification regarding the level of detail of the domain models must correspond to the BEP / EIR.
- The complete and error-free compliance with the specifications regarding the level of detail 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 drawings) is placed in the domain model by the responsible author 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 architecture domain model (native and as IFC file) with all domain models as an IFC reference,
- the remaining domain models (native and as IFC file),
- the last valid positive check reports (as PDF and BCF file),
- the room and equipment book (as XLS file),
- the SAP component list for all care/maintenance/inspection-relevant equipment (as an XLS file), as well as
- the as-built documentation with point cloud (E57 file) 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, drawings, details) including all relevant product information.

For relevant product information, see tables in accordance with ÖNORM A 7010-6, Annex B

The client receives a complete documentation of the structure. Based on this, the future operator can link its technical and commercial management.

List of BIM relevant standards

EN 15643-3:2012	*»Sustainability of construction works – Assessment of buildings – Part 3: Framework for the assessment of social performance«*
EN 16310:2013	*»Engineering services – Terminology to describe engineering services for buildings, infrastructure and industrial facilities«*
EN 17412-1:2020	*»Building Information Modelling – Level of Information Need – Part 1: Concepts and principles«*
ISO 10303-11:2004	*»Industrial automation systems and integration – Product data representation and exchange – Part 11: Description methods: The EXPRESS language reference manual«*
ISO 10303-21:2016	*»Industrial automation systems and integration – Product data representation and exchange – Part 21: Implementation methods: Clear text encoding of the exchange structure«*
ISO 10303-22:1998	*»Industrial automation systems and integration – Product data representation and exchange – Part 22: Implementation methods: Standard data access interface«*
ISO 10303-28:2007	*»Industrial automation systems and integration – Product data representation and exchange – Part 28: Implementation methods: XML representations of EXPRESS schemas and data, using XML schemas«*
ISO 12006-2:2020	*»Building construction – Organization of information about construction works – Part 2: Framework for classification«*
ISO 12006-3:2022	*»Building construction – Organization of information about construction works – Part 3: Framework for object-oriented information«*
ISO 12911:2023	*»Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM – Framework for specification of BIM implementation«*
ISO 16739-1:2024	*»Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries – Part 1: Data schema«*
ISO 19148:2021	*»Geographic information – Linear referencing«*
ISO 19650-1:2018	*»Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 1: Concepts and principles«*
ISO 19650-2:2018	*»Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 2: Delivery phase of the assets«*
ISO 19650-3:2020	*»Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 3: Operational phase of the assets«*
ISO 19650-4:2022	*»Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 4: Information exchange«*

ISO 19650-5:2020 »*Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 5: Security-minded approach to information management*«

ISO/DIS 19650-6:2023-11 (Draft) »*Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 6: Health and safety information*«

ISO 22057:2022 »*Sustainability in buildings and civil engineering works — Data templates for the use of environmental product declarations (EPDs) for construction products in building information modelling (BIM)*«

ISO 23386:2020 »*Building information modelling and other digital processes used in construction — Methodology to describe, author and maintain properties in interconnected data dictionaries*«

ISO 23387:2020 »*Building information modelling (BIM) — Data templates for construction objects used in the life cycle of built assets — Concepts and principles*«

ISO 29481-1:2016 »*Building information models — Information delivery manual — Part 1: Methodology and format*«

ISO 29481-2:2012 »*Building information models — Information delivery manual — Part 2: Interaction framework*«

ÖNORM A 2063-1:2021 »*Exchange of data in electronic form for the tendering, awarding and billing phases — Part 1: Exchange of data concerning service description, tender, offer, works contract and final settlement in electronic form*«

ÖNORM A 2063-2:2021 »*Exchange of data concerning service description, tender, offer, works contract and final settlement in electronic form — Part 2: Consideration of the planning method Building Information Modeling (BIM) Level 3*«

ÖNORM A 6241-1:2015 »*Digital structure documentation — Part 1: CAD data structures and building information modeling (BIM) — Level 2*«

ÖNORM A 6241-2:2015 »*Digital structure documentation — Part 2: Building information modeling (BIM) — Level 3-iBIM*«

ÖNORM A 7010-6:2019 »*Exploitation of objects for contract use — Data structures — Part 6: Requirements for data from Building information modeling (BIM) models over the lifecycle*«

ÖNORM EN 15221-6:2011 »*Facility Management — Part 6: Area and Space Measurement in Facility Management*«

SIA 112:2014 »*Model building planning*«

SIA 405:2012 »*Geodata on supply and disposal lines*«

SIA 2014:2017 »*CAD data exchange — layer structure and leyer codes*«

SIA 4008 »*Pipeline cadastre — Guide to the SIA 405 standard*«

SIA 4013:2021 »*Guidelines CAD data exchange — organisation and planning*«

VDI 2552 Part 1 (2020) »*Building Information Modeling — Fundamentals*«

VDI 2552 Part 2 (2022) »*Building Information Modeling — Terms and Definitions*«

VDI 2552 Part 3 (2018) »*Building Information Modeling — Model-based quantity determination for budgeting, time scheduling, contracting and accouting*«

VDI 2552 Part 4 (2020) »*Building Information Modeling — Requirements for data exchange*«

VDI 2552 Part 5 (2018) »*Building Information Modeling — Data management*«

VDI 2552 Part 6 (2023) »*Building Information Modeling — Facility management*«

VDI 2552 Part 7 (2020) »*Building Information Modeling — Processes*«

VDI/bS-MT 2552 Part 8.1 (2019) »*Building Information Modeling – Qualifications – Fundamental knowledge*«
VDI/bS-MT 2552 Part 8.2 (2022) »*Building Information Modeling – Qualifications – Advanced knowledge*«
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VDI/bS 2552 Part 11.3 (2020) »*Building Information Modeling – Exchange requirements – Formworks and scaffolding systems (in-situ concrete)*«
VDI/bS 2552 Part 11.4 (2024) »*Building Information Modeling – Exchange requirements – Energy consulting*«
VDI/bS 2552 Part 11.5 (2023) »*Building Information Modeling – Information exchange requirements – Elevator technology*«
VDI/bS-EE 2552 Part 11.6 (2024) »*Building Information Modeling – Exchange requirements – fire protection*«
VDI/bS-EE 2552 Part 11.8 (2023) »*Building Information Modeling – Exchange requirements – Factory planning*«
VDI/bS 2552 Part 11.9 (2025) »*Building Information Modeling – Exchange requirements – Building physics*«
VDI/DIN-EE 2552 Part 12.1 (2020) »*Building Information Modeling – Structural description of BIM use cases*«

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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 trained at »Practitioner« level in openBIM Coordination and openBIM Management.

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