VDI Zentrum Ressourceneffizienz

On behalf of:

Federal Ministry
for the Environment, Nature Conservation,
Nuclear Safety and Consumer Protection

of the Federal Republic of Germany

Resource efficiency through Building Information Modelling

Requirements and potential

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1st edition, March 2024

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The brochure was commissioned by the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection.

Introduction

The careful use of natural resources is a key prerequisite for better climate protection and the preservation of our planet's biodiversity. In the construction industry in particular, there is immense potential to reduce resource consumption and greenhouse gases due to the size of the material flows. In this context, improved circularity of building materials used and optimisation of transport routes and the operating phase are important measures. This is where **Building Information Modelling** (BIM) can provide support as an overarching digital working method.

This brochure provides an overview of the requirements that need to be met in order to achieve better resource efficiency. Selected project examples also show how this potential is already being utilised in practice.

Figure 1: Quarry in Southern Germany

Circularity of materials

The course for maximising the resource efficiency of buildings is already set in the very first planning phases.[1] Decisions are made in these design phases that shape the performance of a building over its entire life cycle. But even in later planning phases, close coordination between all those involved in the project is a mandatory prerequisite for achieving the desired sustainability goals. By realising a design that facilitates disassembly and by using materials that can be recycled at high quality, new buildings can serve as raw material stores after the longest possible and most intensive phase of use – and thus make an important contribution to conserving resources. Ultimately, components or component layers that are in good condition and can be dismantled non-destructively can potentially be reused.

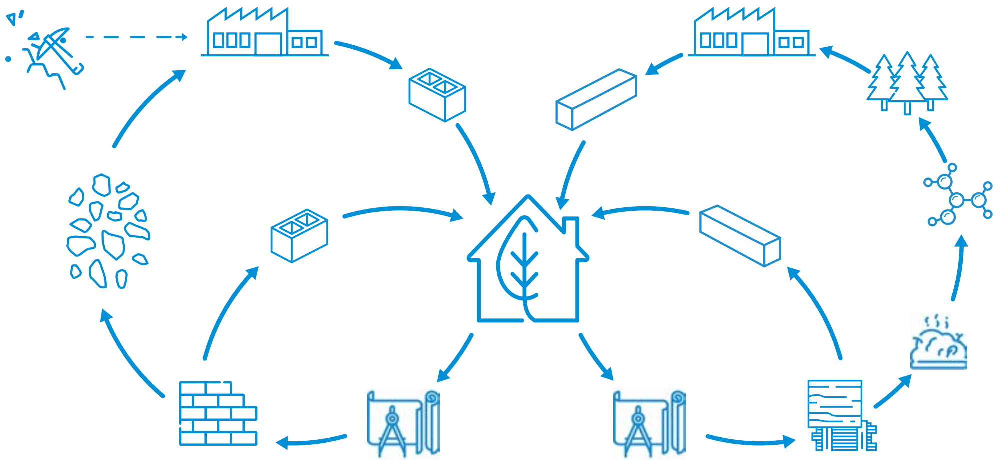


Figure 2: Circularity in a technical (left) or biological (right) cycle, © Werner Sobek AG[2]

If reuse is not possible, however, it should be ensured that 100% of the materials used can be returned to technical or biological cycles (cf. Figure 2).

In the last century, the construction industry was heavily dominated by concrete and steel as well as other mineral building materials. Figure 3 shows the conventional distribution of materials within a typical solid construction building from the late 20th century.

In conjunction with the consumption of resources by the construction industry, the BIM method holds great potential for saving (primary) resources. By bringing together various construction planning experts at an early stage, the entire building's life cycle can be taken into account.

This allows interactions (for example between the building and technical building equipment) to be identified and subsequently optimised. With the help of digital tools, resources can also be conserved right from the planning stage.

The product labelling stored in the digital model makes it possible to ensure a continuous flow of information throughout the entire life cycle. This is one of many important prerequisites for the conversion and reuse of existing buildings, and it is crucial for ensuring recycling of building components at the end of their life cycle (EoL) that is as high-quality and comprehensive as possible.

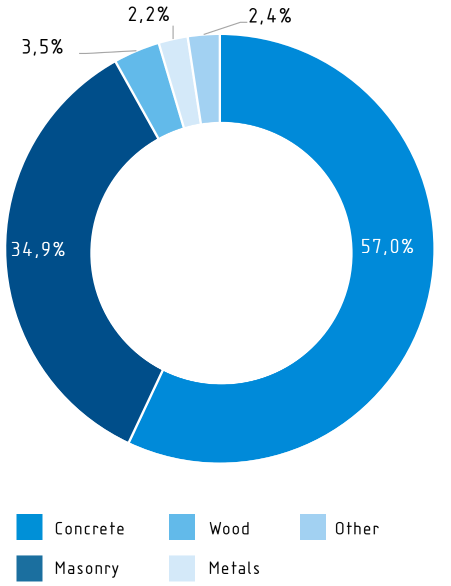


Figure 3: Material composition (by mass) of a residential building with conventional construction, © Werner Sobek AG[3]

What does resource efficiency mean?

Resource efficiency is of particular relevance in dealing with the challenges posed by the shortage of raw materials. The VDI defines resource efficiency as the ratio of a specific benefit or result to the resources used to achieve it.[4] Applied to the construction industry, the benefit is the fulfilment of the function and requirements of a component within a building. Resource expense refers to all natural resources, including raw materials, land and energy sources as well as air and water, but also soil and ecosystem services (cf. Figure 4).

In addition to reducing the amount of primary resources used, the aim is to integrate all construction products into a technical (cf. Figure 2, left) or biological cycle (cf. Figure 2, right). Ideally, this takes place along a recycling cascade that slopes as gently as possible. Resource efficiency not only reduces the consumption of resources but also the consumption of so-called embodied energy or embodied emissions. Here, embodied energy refers to the energy used to construct buildings. It includes the energy required to extract raw materials, manufacture components, transport people, machines, components and materials to the construction site, install components in the building and dispose of them. Embodied emissions are the greenhouse gas emissions (GHG emissions) resulting from these processes. Embodied emissions as a term is therefore more comprehensive, as some production processes, e.g. in the production of steel or cement, CO_2 is also emitted through chemical reactions.

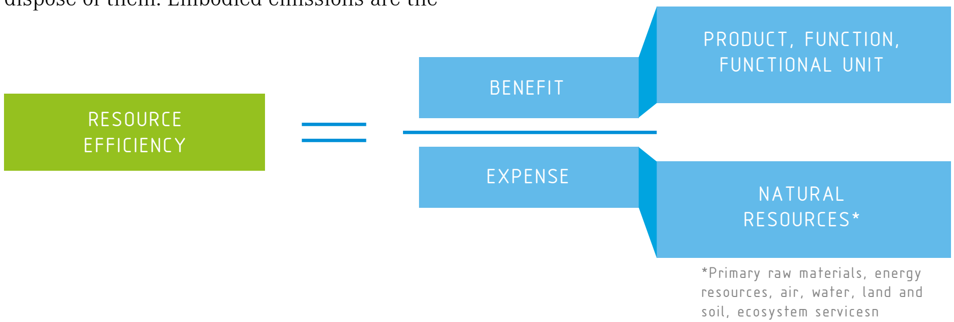


Abbildung 4: Definition of resource efficiency according to © VDI 4800 Blatt 1

What is Building Information Modelling?

„Building Information Modelling refers to a cooperative working method that uses digital models of a building to consistently record and manage the information and data relevant to its life cycle and exchange it between the parties involved in transparent communication or transfer it for further processing.“[5]

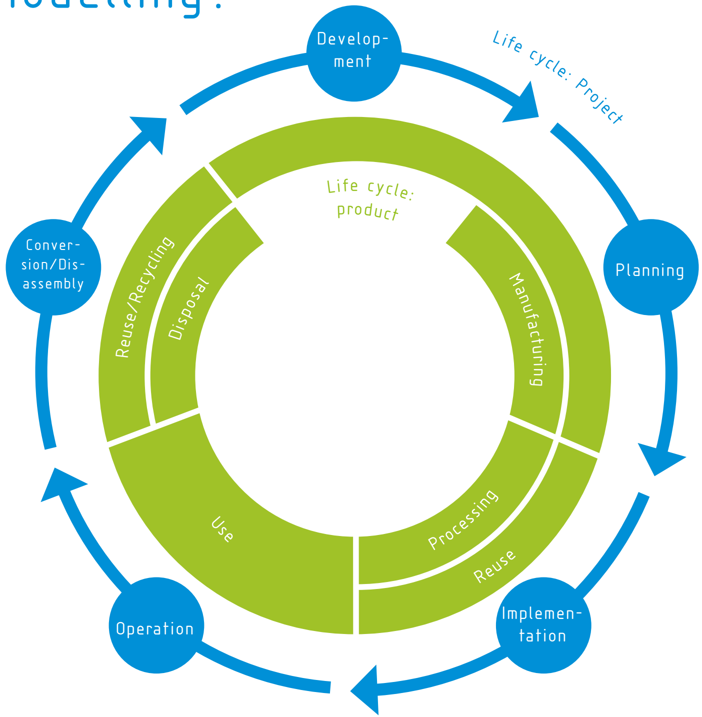


Figure 5: Life cycle phases of a construction project and construction product
© Werner Sobek AG

Definition

By using the BIM method, it is possible to ensure the diverse and sustainable use of all building information by all parties involved in the project over the entire life cycle. A life cycle includes all phases of a building, including all construction products, from the initial ideas, planning, implementation and operation through to conversion and disassembly (cf. Figure 5).

The information provided is brought together in a so-called digital twin. In its listed properties (geometry, attributes, etc.), it reflects the depicted building in the respective life cycle phase. This approach comes with enormous advantages and opportunities. For example, it enables agile revision cycles which can be used to constantly monitor project progress in the planning and construction process, identify problems and find interdisciplinary solutions.

BIM can be used in projects as so-called **closed BIM** or **open BIM** – with proprietary or open data formats.

The use of digital tools and methods is currently categorised into four different BIM levels, which are defined in guideline VDI 2552 Blatt 1[6].

Figure 7 provides a brief overview of levels 0 to 3.

Figure 6: 3D model of an office building, © PantherMedia/SAdesign

BIM levels

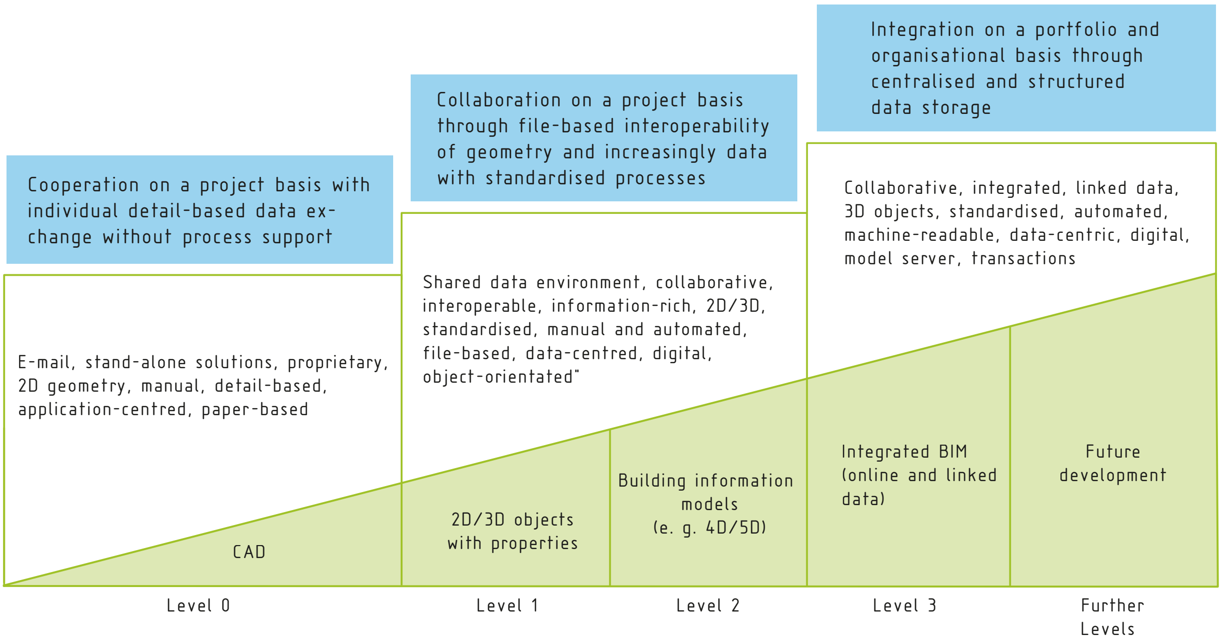


Figure 7: Overview of levels, © VDI 2552 Blatt 1, reproduced with permission of the Verein Deutscher Ingenieure e. V.

BIM use cases

The requirements of the contracting authority for the provision of information to achieve the BIM objectives are defined in the Exchange Information Requirements (EIR) (cf. Figure 8). Based on the overarching project objectives, the project-relevant BIM objectives are identified in order to derive the BIM use cases (UC). For example, the BIM objective of “improved determination of quantity” is derived from the overarching project objective of “cost reliability” and implemented using the BIM use case “model-based determination of quantity”. The EIR represent the contracting entity’s specifications for the realisation of the BIM objectives and are set out in the functional specification document, known as the BIM Execution Plan (BEP), in collaboration with the parties involved in the project.

A UC therefore describes the purpose for which model data is used in a project. The definition of the UCs in the EIR by the contracting entity is a prerequisite for ensuring that the models created contain the information required for implementation (e.g. geometry, attributes).

It must be clearly communicated from which discipline and in which performance phase (i.e. stage of the construction project) the UC is applied. The VDI counts BIM-based coordination, plan derivation, visualisation, cost calculation, bill of quantities creation, construction process simulation and defect management among the most relevant UCs (cf. guideline 2552 Blatt 4).[7]

Based on the VDI’s UCs, BIM Deutschland (Germany’s centre for digitalisation and construction) has published a list of 21 standardised use case designations that can be used as the basis for possible UCs[8] in the EIR and the BIM Execution Plan (BEP). The BIM method is also being adopted by public contracting entities; for example, it has been mandatory for all federal buildings to use the BIM method for new construction projects to be planned since the end of 2022. Three specially defined levels[9] outline a multi-stage introduction of BIM use cases for federal buildings in order to ensure full implementation by 2027.

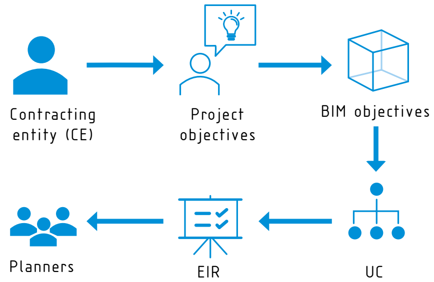


Figure 8: Integration of project and BIM objectives in planning processes, © Werner Sobek AG

Opportunities

In principle, the BIM method can bring considerable advantages that have a positive impact on the efficiency and quality of a project (cf. Figure 9).

Due to the increasing demand for sustainable buildings, the traditional 2D planning process must undergo a change.[10] Here, the creation and possible analysis of data models of all relevant specialist planners offers immense potential to review and optimise the design in the early planning phases and reduce the use of resources to a minimum.

Integrating sustainability aspects into the BIM process has the following advantages:

- Model-based life cycle assessment and life cycle cost calculation
- Tracking of environmental impacts (e.g. emissions, water consumption, energy requirements, etc.) when modelling with few or ideally no intermediate steps
- Sustainable, positive effects on the design process, e.g. variant analyses using simulations (also via virtual/augmented reality) enable design decisions to be made on the basis of ecological aspects
- Documentation of the building materials used enables the planning of future dismantling and reuse and/or recycling
- Reduction of consumption during operation through technical monitoring and target/actual comparisons
- Use of the model for sustainability certifications

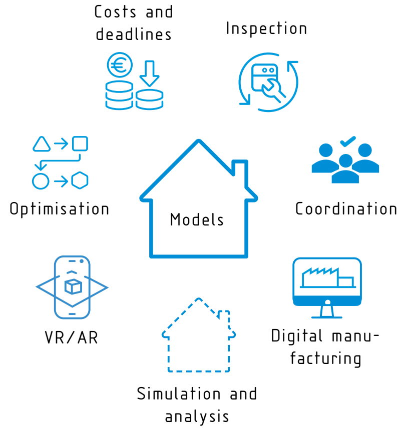


Figure 9: Performance areas of the BIM method, © Werner Sobek AG

The challenge

A major challenge is to raise awareness among all parties involved in the project (starting with the contracting entity) of the need to integrate sustainability aspects at an early stage, define the resulting requirements in the UCs of the EIR and monitor their implementation over the course of the project.

Figure 10 illustrates the influence exerted in the initial performance phases and assigns the planning-related UCs to the course of the project.

> The models created with BIM offer a valuable pool of data and information that should be utilised by local councils and cities (while ensuring data protection). This applies both at building and district level.

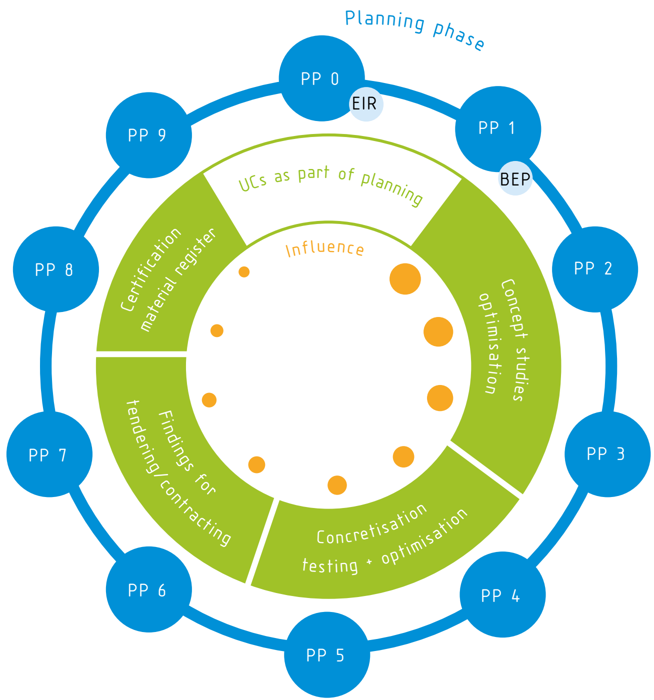


Figure 10: UCs during planning for each performance phase (PP),
© Werner Sobek AG

Requirements for EIR and BEP to increase resource efficiency

The readiness for early integral planning is a prerequisite for the application of the BIM method and the realisation of sustainability goals. This allows the design phase to significantly influence a building's resource efficiency, e.g. through its dimensions, orientation or choice of materials.

With BIM, buildings are planned for their entire life cycle – from design to disassembly. In the **Exchange Information Requirements (EIR)**, the contracting entities define the BIM project objectives as well as the information and strategies required to achieve them before the start of planning and construction.

The EIR thus fundamentally answer the question: "What is needed when and by whom?" and form the basis for the jointly developed **BIM Execution Plan (BEP)** in terms of content. These specifications, in particular the UCs, therefore also create the contractual basis for comprehensive consideration of sustainability aspects.

Figure 11: Teamwork,
© PantherMedia/PeopleImages.com

Exchange information requirements (EIR)

The BIM method itself already supports sustainable construction use cases through the centralised, transparent provision of information and its maintenance.[11] However, in view of the constantly growing demands on buildings in terms of resource conservation and energy saving, more explicit BIM objectives/UCs should be introduced in the EIR. It is also important to ensure the required information delivery times with the necessary data and level of detail. The following key topics should be taken into account in new or expanded UCs in future:

- Model-based building life cycle assessment (LCA) to calculate the environmental impact categories, e.g. Global Warming Potential (GWP)
- Model-based generation of the Building Resource Passport (BRP) to evaluate the recycling potential and the ecological influences and as a decision-making aid or optimisation tool in planning
- Data recording and exchange in a model for the entire life cycle to determine the life cycle costs (LCC)
- Model-based simulations of daylight, ventilation, acoustics, useful energy requirements through to the construction process, logistics, etc. (also using VR/AR)
- Use of models for sustainability certifications (DGNB, LEED, BREEAM, etc.)
- Early involvement of users and operators
- Application of the principles of “lean construction”[12] in all phases of a project to minimise any waste

BIM Execution Plan

The stakeholders' BIM Execution Plan (BEP) is a response to the EIR and provides details and information on how and when the stated project objectives and UCs are to be delivered in accordance with the schedule and how the responsibilities of the individual team members are to be allocated.

In order to implement the new UCs mentioned above, the BEP must outline in particular the information requirements that represent an efficient sustainability assessment and which differ depending on the project phase, methodology and certification system.

Model-based LCAs/BRPs require, for example, the linking of project-specific BIM data with building material databases: generic datasets such as in ÖKOBAUDAT or manufacturer-specific datasets (Environmental Product Declarations – EPD).

The Level of Information Need (LOIN) for each model object and performance phase must be determined in conjunction with this. Corresponding attributes and modelling requirements must also be formulated to ensure a link between the model and the database.

In addition to the general component information on component layers, material properties, geometry, quantities and masses, information on the building's energy requirements must also be available as an attribute in the model for a complete life cycle assessment. A model-based LCC calculation requires information on maintenance intervals, service life, costs, etc. and a categorisation of the elements and rooms (e.g. according to DIN 276/277). For (climate) simulations, other databases such as weather datasets can be linked to the model.

In the future, standardisation of modelling guidelines and use cases will be decisive for this form of information requirements in order to ensure automation with regard to sustainability assessment and certification. The first national standards are expected in the future as part of the guideline VDI 2552 Blatt 11.4 "BIM; Energy consulting" and from the buildingSMART "BIM and Sustainability" expert group.[13]

Integration into building phases

The integration of sustainability aspects and the resulting assessment/balancing can take place over the entire life cycle of a building and pursue different objectives. LCA/BRP/LCC calculations and determinations in early planning phases can, for example, be used for variant and concept studies or for optimising comparisons of individual components and materials.

In execution planning, specific information about a building and its (technical) equipment is available that enables stakeholders to carry out detailed balancing and determine areas with further optimisation potential (e.g. by comparing materials/EPDs).

With careful model maintenance, the as-built model can be supplemented with information from the manufacturers once the building has been

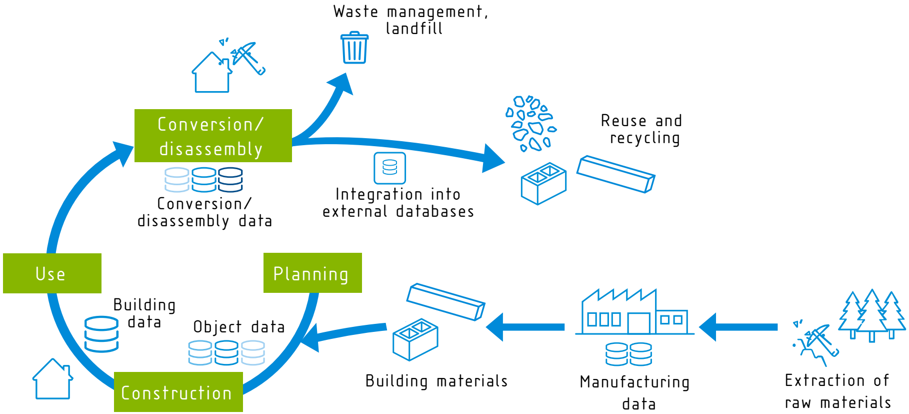


Figure 12: Life cycle of buildings and data, © VDI ZRE[14]

constructed. This detailed model can not only be used for verification procedures in certifications, it also facilitates maintenance, preservation, refurbishment and conversion work. The processes documented in the model make it possible to plan efficient demolition or disassembly at the EoL of a building. This helps to identify the recycling potential of the building materials.

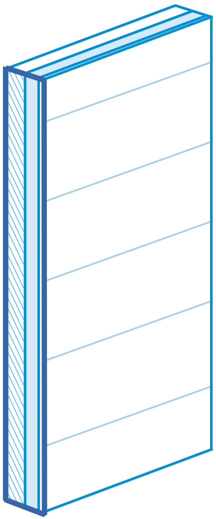
In terms of implementation, particularly with regard to open-BIM projects, the optimisation of interfaces and data consistency throughout the entire life cycle is extremely important (cf. Figure 12).

Model requirements

Structure and information

Implementing the additions to the EIR and BEP to include sustainability aspects requires the specialist disciplines to be more attentive with regard to the model structure and the required data and information (so-called attributes) in the respective specialised models (cf. Figure 13). In addition to the definition of attributes, the time of attribution must be defined and possible links with other applications must be ensured. In the future, guidelines will define these requirements in order to implement subsequent analyses and simulations as well as certifications and the creation of Building Resource Passports. VDI/bS 2552 Blatt 11.4 pertaining to information exchange requirements for life cycle assessment is currently in progress. However, as these definitions are not yet standardised, project-specific agreements and specifications must be made. For example:[11]

- Translation of the requirements into processable model information,
- Construction of model elements in such a way that allows them to be analysed unambiguously and individually (e.g. it should be possible to assign a separate service life to each component layer),
- Agreement of a specific material nomenclature to enable automatic material identification for the LCA analysis tools or the BRP of a specific project,
- Definition of attributes for each model object that outline the environmental impact (e.g. GWP), the use of resources (e.g. primary energy or raw material demand) or other environmental information (e.g. recyclability, water consumption),
- Recording of the correct geographical project location in the model (IfcSite),
- Other attributes required in accordance with the UCs must be agreed with the contracting entity, operator and, if applicable, the certification body/certifiers,
- Recording of suitability for disassembly (e.g. ability to separate components/materials) as an attribute,
- Consideration of model requirements for digital platforms for circular material cycles.



Properties type

Family: Generic wall
Type: Wall 1

Attributes type

Attribute	Value
Construction	
Structure	...
Thickness	0,38
Function	exterior
Identity	
Name type	ext. wall
Manufacturer	Firma AG
Description	
U-value	0,35 W/m²K
Fire protection class	A1
Costs	300 eur/m²
DIN-costs group	330
IFC type	IfcWall

Structure

Type: Wall 1

Layers

Function	Material	Thickness
1 Coating	int. plaster	0,01
2 Supporting structure	CLT	0,20
3 Dämmung	Rock wool	0,15
4 Facade cladding	Metal panel	0,02

Material

Function: Insulation
Name: Rock wool
Manufacturer: Product SE

Attribute	Value
Environment. impact	
GWP	
Use of resources	
Primary energy	
Raw material demand	
Recycability	
reusable	☐
recyclable	☐
downcycling	☐
dispose	☐
Suitability for disassembly	
non-destructive	☐
by type	☐

Figure 13: Example component structure with attributes,
© Werner Sobek AG

Linking

For projects modelled using BIM, the **Information Delivery Manual (IDM)** describes the process of information delivery by the people involved, including their responsibilities and the associated interfaces and deadlines: "Who needs what information from whom, when, in what quality and in what form?"

It therefore defines the information **Exchange Requirements (ER)**, in the process. These must be supplemented with regard to sustainable UCs in order to enable new links.

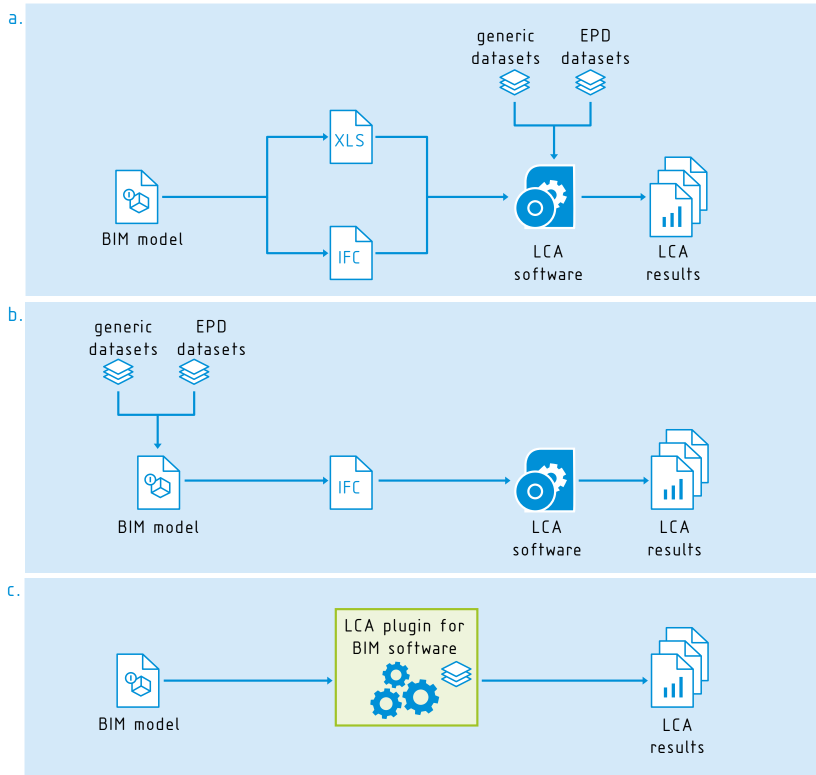


Figure 14: Possible strategies for integrating the building life cycle assessment with BIM, based on CC BY 3.0 Wastiels/Decuypere[15]

In order to offer automated, model-based life cycle assessment in the future, the following basic strategies can be pursued, for example (cf. Figure 14):

a. Import of model objects (IFC) or masses/quantities (XLS) from the models into LCA software applications in order to link and analyse them with stored datasets

b. Direct enhancement of model objects with generic or EPD datasets, allowing these objects to be linked via IFC in an LCA software

c. Use of an LCA plug-in within the BIM software that (semi-)automatically creates a link between the model objects and the stored datasets

Similar strategies can be defined to create BRPs, determine LCCs, for links with simulation applications or with future optimisation tools for sustainable construction (potentially AI-based).

In addition to the links to model-based life cycle assessment and simulation in the planning phases, further links are necessary in the life cycle of a building. This includes linking model data to platforms for circular material cycles in the construction sector. These digital marketplaces will be used to offer construction products from disassembly, surplus/incorrect orders during construction or factory seconds. The first platforms have been developed and are already in use. Until now, the model requirements have been defined by the individual platforms and must therefore be taken into account when creating as-built models.[16] Despite today's uncertainties, it is important to disseminate this platform concept more widely.

More cost-effective second-hand construction products can be taken into account for future planning, disassembly costs can be reduced and resource consumption can be minimised. Construction products used should therefore already be digitally documented in order to enable circular material cycles.

In the future, digital recording and documentation will make it possible to issue Building Resource Passports for individual buildings and provide the option of recording all buildings in an urban area and their construction products in a central database. This forms the digital basis for implementing urban mining – i.e. the integrated management of the anthropogenic urban raw material store. For individual developers, this enables model-based sustainability certification of the building and thus compliance with the limit values required in the future, which will result from ESG requirements as part of the EU Green Deal.

Project examples

The Q

The project involves the revitalisation of a former shipping hub in Nuremberg, which is being used as the site for development of a mixed-use district with retail, office, residential and social spaces. The existing post-war modernist building is a listed building and thus provided a structural framework that was to be used to revitalise the neighbourhood.

In addition to the activation of the district, the self-imposed requirement for sustainability and the treatment of the listed building, particularly with regard to the compatibility of the facade design with today's energy standards, posed challenges.

Figure 15: The Q, visualisation, © kister scheithauer gross architekten und stadtplaner GmbH

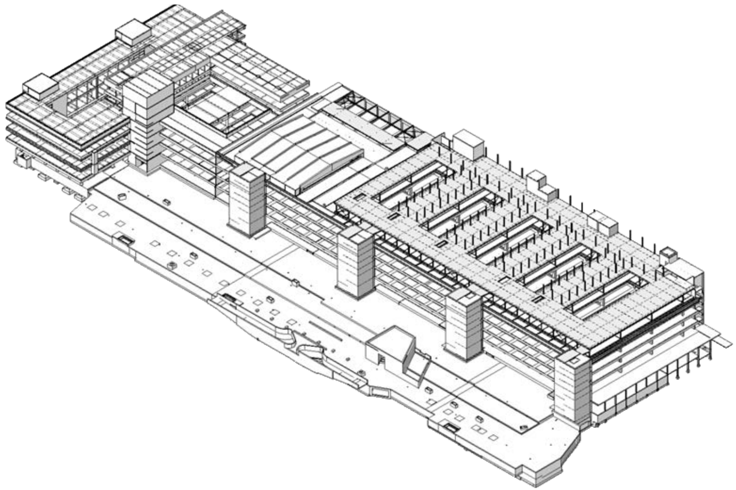


Figure 16: The Q, BIM model, © Werner Sobek AG

Due to the large depth of the building, the integration of atriums was essential to meet the change in utilisation requirements and thus presented a further challenge for the structural support system.

With the help of BIM planning, it was possible to compare a conversion with a new building in advance and determine the resulting CO2 emissions. Based on this analysis, planners were able to identify that the new building would have generated around 160% of the emissions caused. In absolute terms, the savings amount to around 33,000 tonnes of CO_2 equivalents.

The Q

Construction site	Nuremberg, Germany
Developer	Gerch Nürnberg The Q GmbH
Architecture	kister scheithauer gross architekten
Structural design	Werner Sobek AG
Gross floor area	170.000 m^2
Completion	2024
Awards	polis Award 2022

The Cradle

The Cradle is a six-storey office building in Düsseldorf's Medienhafen harbour district that is based on the cradle-to-cradle (C2C) principle and uses a timber hybrid construction method. The declared aim is to become the cradle of innovation and to provide impulses for the future of construction. The planning architects HPP wanted to make fundamental decisions during the early planning phases in close cooperation with other planning parties in order to act as sustainably as possible.

In BIM-based planning across all trades, the interoperability of the planning models and their constant exchange play a particularly important role.

Various programmes were used, with data exchanged via the IFC interfaces. Here, the BIM model serves as the basis for the building physics calculations and the detailed quantity determinations. The circular concept was integrated into BIM planning for the first time.[17]

The materials and components were assigned an individual number in the BIM model for this purpose. With this unique identification, all relevant data can be transferred to a material register. This stores the information on the used building materials and products in the long term.[17]

Figure 17: The Cradle, BIM model (section), © HPP Architekten

The residual material values, dismantling options, recyclability and separability can be viewed, e.g. in the event of conversion or dismantling. By linking to other databases, the materials can also be analysed in terms of material health and ecological impact. Building product manufacturers benefit from knowing at an early stage which materials will be needed in the future. They can also dismantle, take back and reuse components or recycle them by type.[17]

Figure 18: The Cradle, visualisation, © INTERBODEN Group/HPP Architekten; visualisation: bloomimages

The Cradle

Construction site	Medienhafen, Düsseldorf, Germany
Developer	Interboden Gruppe
Architecture	HPP Architekten
Structural design	knippershelbig
gross floor area	7.200 m^2
Completion	2023
Awards	various incl. BIM Heinze ArchitektenAWARD 2020

Former printing works in Essen

The production hall in Essen, which was vacant due to a site closure, was digitally recorded in order to analyse the potential for further use. Using surveying tools, the existing structure was translated into a virtual building model based on point clouds.

Among other things, surveying and inventory modelling make it possible to provide model-based support for the life cycle assessment and record the geometries. In addition, areas can be analysed in accordance with DIN 276 and rental spaces can be determined.

Figure 19: Former printing works in Essen by the Greyfield Group, © Greyfield Group

In addition to the survey data, the digital twin is supplemented by 2D plans and fed with further information. On this basis, geometric and semantic information can be generated to create a BIM-based as-built model.

This model provides the basis for the further planning process and enables the creation of variants with a direct comparison of selected parameters such as the use of materials or the emissions caused.[18]

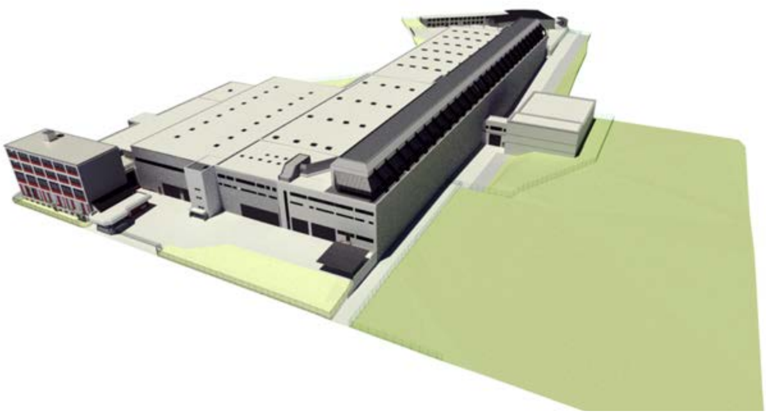


Figure 20: Former printing works in Essen by the Greyfield Group, BIM model (rendering), © intecplan Essen

Former printing works in Essen by the Greyfield Group

Construction site	Essen, Germany
Developer	Greyfield Group
BIM management	intecplan
Gross floor area	30.000 m²
Processing period	08/2021 - 04/2022

Summary and outook

The comprehensive application of BIM provides great potential for new possibilities and opportunities for those involved in construction, particularly with regard to sustainability. BIM makes it possible to comprehensively optimise buildings in terms of their efficiency and costs. By integrating new attributes and implementing auxiliary tools (e.g. for determining resources/emissions), automated compilations and calculations are made possible and it is significantly easier to create variants and direct comparisons. This facilitates gradual progress towards the desired guideline values and optimises the work process in general.

Automating these processes also helps to save time and money. It also facilitates the preparation of such compilations. This helps to accelerate their integration as an integral part of the regular editing processes to become a standard way of working. Small and medium-sized projects in particular benefit from the fact that comprehensive sustainability assessment has become standard practice; such consideration was previously not possible for economic reasons, or only possible to a limited extent.

Integrating the sustainability aspect into the work with BIM is the next logical step in view of the major challenges facing the construction industry. Interdisciplinary collaboration between numerous experts is both a prerequisite and a guarantee for joint, solution-orientated action and successful project completion.

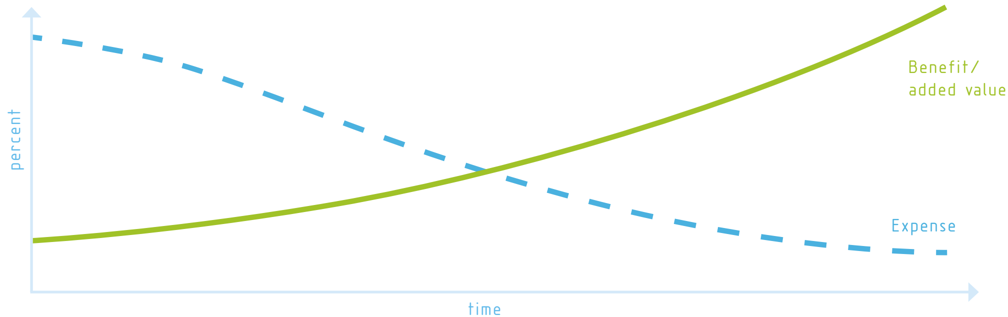


Figure 21: Expenditure-to-added-value diagram, © Werner Sobek AG

BIM-based LCA and LCC

Both the systematic compilation of a building's environmental impact in the form of an LCA or life cycle analysis and the compilation of the costs incurred using the LCC method (i.e. life cycle costing) are tools that have become established in recent years for the assessment and documentation of building properties. These create a clear overview and allow a building's characteristic values to be compared. The procedure for the holistic consideration of environmental impacts over the life cycle is described in DIN EN ISO 14040/14044.

Processes can be gradually automated by integrating sustainability attributes. The previously manual calculation of embodied emissions and primary resource consumption via Excel lists can be automated by linking product information in the form of attributes in the digital model and then output in tabular form if required. The attributes are linked to the materiality, which includes the material origin and the EoL scenario of the building materials.

This direct link to the virtual building data model, which reacts immediately to changes in dimensions and construction, generates a constantly updated calculation of the ecological sustainability of a building and can thus directly influence decision-making in the planning process. In addition, cooperation between the different parties involved in planning is promoted early on in the process, making the direct impact of the joint solutions more visible.

Certifications

In addition to simple compilations on the environmental impact of buildings, there are also assessment systems that are usually prepared by third parties and serve to provide a neutral assessment of buildings with regard to sustainability aspects by using various criteria.

Well-known assessment and certification systems include those of the German Sustainable Building Council (DGNB), the US Leadership in Energy and Environmental Design certification (LEED) and the British Building Research Establishment Environmental Assessment Methodology (BREEAM).

Many of these certification systems are based on national legislation and are therefore regional in nature. The DGNB certification is a good example to illustrate the objective. First of all, the system is available in different variants on all scales. This means that districts, buildings or even just interiors can be examined and evaluated.

The content of the system is based on three key paradigms: a life cycle approach, a holistic understanding of sustainability and a focus on performance. In contrast to the LCAs, the DGNB certification also includes economic and social requirements as well as process, site and technical qualities in the assessment alongside the ecological aspect.[19]

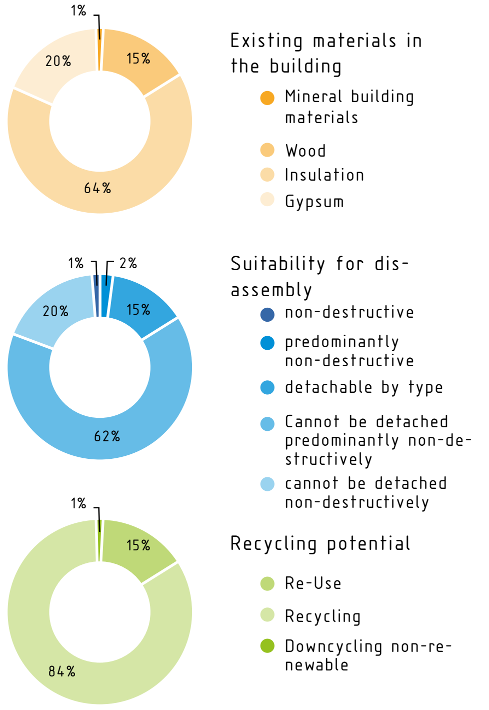


Figure 22: Detail of a Building Resource Passport (example), © Werner Sobek AG

Building Resource Passport

The digital Building Resource Passport is a measure announced by the German federal government in 2021 with the aim of creating a common, universally valid basis for taking greater account of the use of embodied energy and emissions as well as life cycle costs and achieving a circular economy in the building sector in the long term.[20] Although the government has not yet made any concrete statements regarding the implementation, the DGNB has already published a passport with possible content-related points of consideration and detailed requirements.[21]

Basically, resource passports should be drawn up in a similar way to the energy performance certificate for buildings and contain key information on resource consumption, global warming potential and recyclability (cf. Figure 22). The necessary information should be stored in order to promote a more recycling-oriented attitude and make the best possible use of resources. This could make urban mining easier in the future and help to utilise resources efficiently during renovation and demolition. In the long term, the Building Resource Passport will serve as the basis for a consistent circular economy in the construction sector, creating a bridge between early and late life cycle phases (product design and product recycling). For the system to work, data transparency is required regarding the used materials and components, their current values and ownership structures.[22]

The digital Building Resource Passport is therefore essential for sustainable building management with a comprehensive life cycle assessment. The creation of such a passport can sustainably improve understanding for the development, operation and EoL of buildings. In addition, such an instrument not only promotes transparency and trust but also helps to make well-founded political and financial decisions and thus ensures that resources are utilised efficiently.

A digital Building Resource Passport should be able to document the entire life cycle of a building and provide seamless access to an unlimited amount of data. The use of a cloud-based system enables easy access and remote collaboration between all parties involved.[23]

There is an urgent need to prioritise sustainability considerations in (new) construction projects. Using political instruments such as the EU taxonomy, CO2 consumption limits or, in the future, potential mandatory Building Resource Passports, incentives can be created to prioritise these aspects as early as in the construction planning and execution stages.

Glossary

Attribution	Labelling of model elements with further information in the form of a name and value
BCF - BIM Collaboration Format	Open file format based on XML that supports coordination in BIM processes
BEP - BIM Execution Plan	Document that describes the basis for BIM-based collaboration in the project. The BIM Execution Plan sets out the objectives, organisational structures and responsibilities, provides the framework for the BIM services and defines the processes and exchange requirements of the individual participants[24]
BIM - Building Information Modelling	Methodology for planning, construction and operation of buildings with a collaborative approach based on a digital building information model for shared use
Building Information Model	Object-based digital mapping of the physical and functional properties of a building. The term refers to a coordinated overall model that is made up of one or more specialist and sub-models of individual specialist planners (architectural model, structural model, TBE model, etc.); usually a central BIM component
BRP - Building Resource Passport	Document summarising the individual key information on the resource consumption of a project
CDE - Common Data Environment	Shared data environment (BIM-compliant data platform)
EIR - Exchange Information Requirements	Requirements of the contracting entity/entities for the delivery of information from the contractors, taking into account the defined BIM objectives and applications
EPD - Environmental Product Declaration	Document in which the environmentally-relevant properties of a product are outlined in the form of neutral and objective data[25]
ESG - Environmental Social Governance	Environmental, social and responsible corporate governance criteria
GWP - Global Warming Potential	describes the potential of a gas to warm the earth's atmosphere compared to CO_2.
IFC - Industry Foundation Class	Independent, open data format for exchanging model-based data and information in planning, execution and operational phases

LCA – Life Cycle Assessment	Compilation and assessment of input and output flows and potential environmental impacts of a product system during its life cycle [26]
LCC – Life Cycle Costing	Life cycle cost calculation
Lean Construction	Continuous process practised during the creation of a construction project to eliminate waste, meet or exceed customer expectations, focus on the entire value stream and strive for perfection[11]
LOD – Level of Development	Degree of completion of the specialist building models for a specific project phase and for the release of BIM applications
LOG – Level of Geometry	Geometric level of detail – the level of detail of geometric model elements in specialist building models
LOI – Level of Information	Depth of information requirements
LOIN – Level of Information Need	Alphanumeric level of detail – degree of attribution of the model elements in specialist building data models
Object-oriented modelling	Construction of a digital model using model elements such as walls and doors, not on the basis of areas and lines. In addition to the geometry, these objects also have other linked information such as material and physical characteristics. Construction of components as a coherent and linked object with attributes in contrast to the traditional purely geometric representation using individual lines, areas and volumes
Resources, used here for: natural resources	These include renewable as well as non-renewable primary raw materials, physical space (land), environmental media (water, soil, air), flowing resources (e.g. geothermal energy) and biodiversity[26]
TBE	Technical Building Equipment

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The brochure was commissioned by the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection.