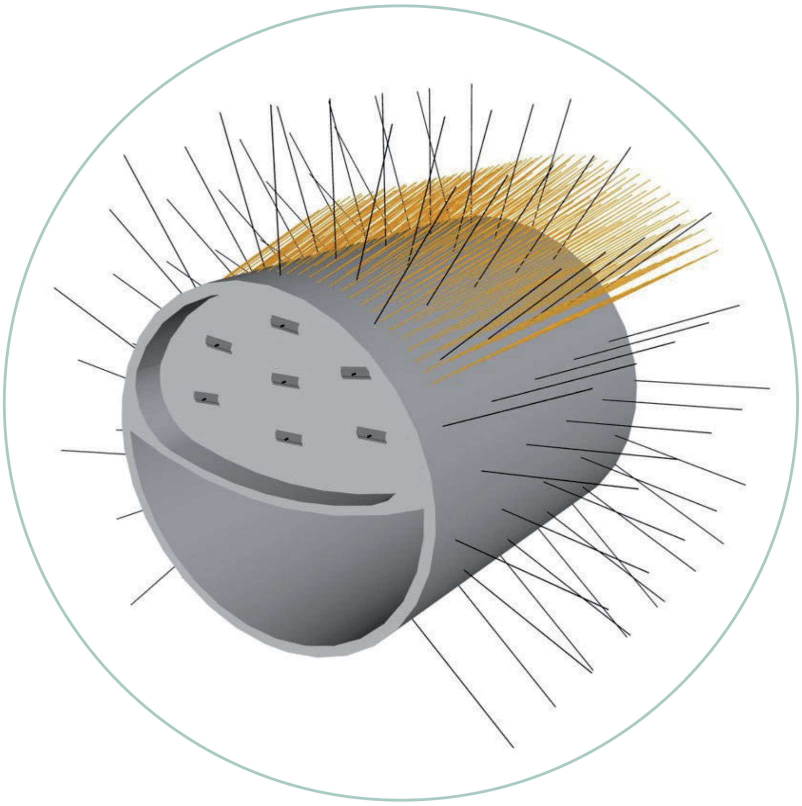

Digital Design, Building and Operation of Underground Structures

Model requirements – Part 1

Object definition, coding and properties

Supplement to DAUB recommendation BIM in Tunnelling (2019)

DAUB working group

Deutscher Ausschuss für unterirdisches Bauen e. V.
German Tunnelling Committee (ITA-AITES)

Digital Design, Building and Operation of Underground Structures. BIM in Tunnelling
Model requirements – Part 1: Object definition, coding and properties
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Publisher
Deutscher Ausschuss für unterirdisches Bauen e. V. (DAUB)
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November 2020

Index

Preamble

In order to ensure sustainable use of the many sources of information in infrastructure construction, it is necessary that attention is also paid to digitalisation in underground construction.

Recommendations of the German Tunnelling Committee DAUB normally provide „best practice" solutions for underground construction in the German-speaking countries. The DAUB recommendation „Digital Design, Building and Operation of Underground Structures – BIM in Tunnelling" published in May 2019 was produced with the objective of providing a basic understanding of the application of BIM in tunnelling. Based on this recommendation, a working group „BIM im Tunnelbau" has now concerned itself with further differentiation of the model requirements specifically for underground construction in order to standardise and homogenise the approaches developed on the first pilot projects. The present document explains a basic understanding of the model structure and should provide uniform descriptions for typical objects in tunnelling and the associated object information. A basic structure for object coding is presented for the unambiguous identification of individual objects in a project.

It is to be expected that this recommendation will be successively revised in the coming years to suit further developed requirements.

The present document is the start of a process of fixing various aspects described in the recommendation „Digital Design, Building and Operation of Underground Structures – BIM in Tunnelling", which will be continued in further parts.

1 Introduction

1.1 Starting situation

In order to enable the implementation of BIM in tunnelling, the process needs to further established or standardised. Nevertheless, the following basic requirements can be stated for model creation in BIM projects:

- Collection of the project basics
- Linking of 3D models with the cost estimate (BOQ), scheduling and other information and processes
- Necessity of a high level of detail with numerous objects (construction elements and machines)
- Need for the unambiguous assignment of objects to various processes and information
- Compatibility of the models for information transfer, independent of author

In order to meet the above basic requirements, the appropriate structures and definitions have to be developed for each project in the various consultancies and companies. On BIM projects, such structures are defined for each specific project in the BIM execution plan (BEP).

The objective of this recommendation is to provide standardisation for the project structure and the descriptions used.

This results in the following tasks for the working group:

- Creation of a basic understanding of the model structure
- Identical naming of objects independent of the author
- Identification and definition of the object information (features and attributes)
- Distinct labelling of different objects with a defined object code to establish the relationship between model and, for example, schedule or cost planning (3D, 4D, 5D)

Furthermore, the resulting model structure with the object definitions and the associated features can be used as the basis for the preparation of a standardised object-oriented bill of quantities.

1.2 Scope of application and target audience

This recommendation is intended for all parties involved in underground construction. The fundamental requirements presented within this document can be used in the planning and design of all underground construction works. It should already be applied consistently in the design phase. Continuous application of this approach should then be consistently maintained and implemented through the approval phase, the tendering process, the construction phase and later, during the operating phase.

1.3 Distinction

The different activities involved in underground construction depend on the intended use and construction process of the respective project. There are very often interfaces to structural and special foundation engineering, buildings, road works, railway construction and tunnel installations. In order to provide a clear distinction, this document focuses on the underground construction process in the design phase, during construction and later operation including the necessary equipment and spaces. Interfaces to other disciplines are only shown schematically.

2 Model structure

The model is the basic tool for the application of BIM and therefore has to be correctly formed, both functionally and technically. Due to the wide variety of construction projects, several consultants and contractors are often involved in the modelling process.

In this section, the terms below are described as a general overview.

2.1 Coordination model

A coordination model **(Figure 2.1)** is a model assembled from various discipline models for purposes of design coordination. Due to the usual project scope in underground construction, those models may represent project areas/sections or lots. One example would be the coordination model „Tunnel". By combining the discipline models „Lining" and „Drainage", for example, the levels for the drainage design can be discussed at an early stage.

2.2 Discipline model

The discipline model contains specific information from the single specialist designer in charge of their discipline. Those designers involved in the project create at least one discipline model, with the spatial interfaces and project coordinates being agreed among them. For underground construction, for example, the discipline models tunnelling, lining, drainage or fire protection can be used.

In order to ensure clear structuring and for performance reasons, it can be advantageous to divide the discipline model into individual sub-models.

2.3 Sub-models

The sub-model forms a defined part of the model of the specialist designer and is geo-referenced to the discipline model. Splitting of a discipline model into sub-models is only necessary when demanded by requirements or size of the project. It is also advisable to use sub-models for the design of intermediate construction states, e.g. the TBM arrival into a shaft.

2.4 Object groups

An object group is a grouping of several objects, which leads to a final product from different assembly processes.

One example of this would be the temporary shotcrete support layer. The shotcrete layer is described for the object coding (see **Section 3.2**) as „Primary lining" and contains the objects „Lining", „Sealing support", „Reinforcement", „Rock bolts" and if necessary further objects. **Appendix 1** gives an overview

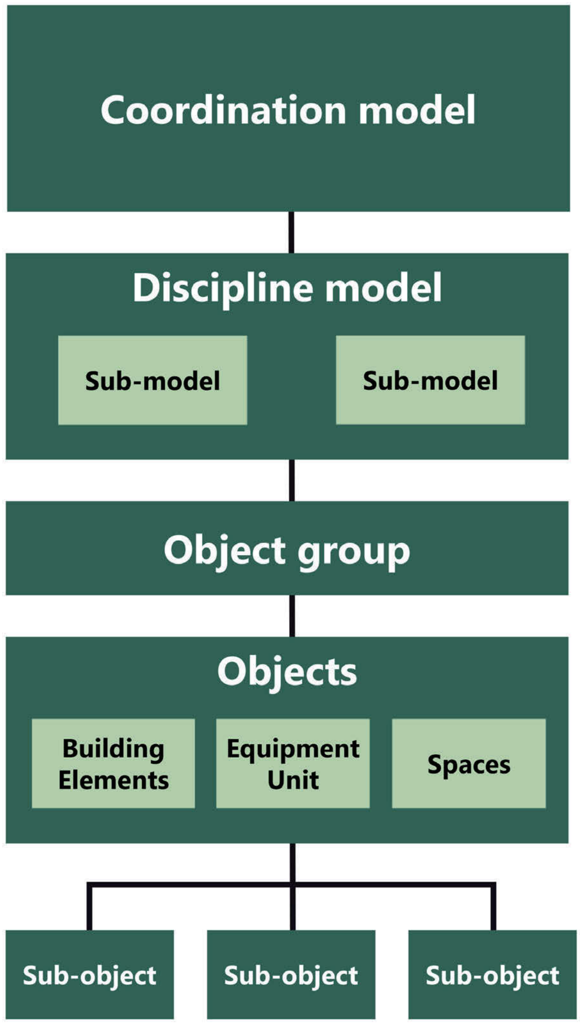

Figure 2.1 *Modell structure*

of the possible object groups under the heading „Appendix 1 - Object table" in column „Level 090 – Object group".

2.5 Object (element, equipment or space)

An object is an individual model element containing stored information. It can be used to show the final structure, fit out, temporary structures or equipment for the construction process.

Differing specifications for the description of an object/element or equipment are common within the construction industry and in standards. Therefore, the DAUB recommends the following definition of terms, which are also shown in **Figure 2.1**:

- An **Element** is an object, which is necessary to represent the completed state of the structure
- An **Equipment** Unit is an object, which is necessary to construct the elements
- A **Space** is an immaterial object, which is assigned a function, e.g. a clearance profile, working space etc.

2.6 Sub-object

Sub-objects are mainly necessary for the design of detailed solutions. Sub-objects represent different parts of the object and thus show the inner quantities of the object. The introduction of a sub-object is also sometimes necessary to be able to continuously represent the generic, hierarchical structure. The object „Rock bolts", for example, can show the sub-objects Rock bolt bar, Rock bolt mortar or Head plate.

3 Object catalogue

3.1 Description

The object catalogue is a structured collection of all objects and sub-objects necessary to model an underground structure with relevant detailing. Appendix 1 shows the object catalogue as a list with a hierarchical structure of 14 Levels.

The levels and the classification system for unambiguous identification of the (sub-) objects are explained in **Section 3.2**.

As soon as the (sub-) objects have been modelled as parameterised templates, they can be used for any model in underground construction, with the relevant project-specific adaptations. The 3D model created in this way serves as the basis for further use-cases based on the BIM methodology. The unambiguous identification of (sub-) objects provides the model with the following capabilities.

- Filtering
- Quantity take-off and calculations
- Linking to activities from the construction schedule (4D, construction progress simulations)
- Derivation of the bill of quantities (BOQ)
- Linking with items or costs in the BOQ (5D, cost curve)
- Implementation of target-actual comparisons
- Referencing of documents, photos, external data etc. to the relevant (sub-) object

Amongst others, the two most important principles of the BIM methodology are:

1) In order to avoid unnecessary information interruptions, the model serves as a „Single Source of Information" through all project phases.
2) All project parties collaborate on the model.

A precondition for the implementation of this approach is a collaboratively defined model, which fits a generally valid standard. Standardisation of the object catalogue is therefore essential and includes not only the listing of the (sub-) objects but also their

- naming
- name abbreviation
- hierarchical structure and
- unique positional description

Experts from the DAUB working group „BIM im Tunnelbau" (AK BiT) have therefore collaborated in order to produce this fundamental basis. The collection of the experts' experience in modelling various underground projects and intensive discussions result in the object catalogue shown in **Appendix 1**.

The development of the object catalogue focuses on the technical content that an object catalogue for underground construction should contain. The catalogue contains not only (sub-) objects, which purely relate to underground construction works. It also includes related disciplines that commonly occur in the course of the project developing and execution process.

Beginning with the familiar 2D drawings from underground construction, the individual (sub-) objects are prepared, added to the catalogue, the hierarchical assignment defined, and a suitable name is given. In order to illustrate this, an example of a tunnel excavation with temporary support is shown in **Figure 3.1** to **Figure 3.3,** and an example of a permanent lining is shown in **Figure 3.4** to **Figure 3.6**. **Appendix 4** rovides a collection of generic objects.

The object catalogue prepared as part of this recommendation is available for download as an original Excel file on the homepage of the DAUB. In this file, assignments of the (sub-) objects are made in additional columns so that filtering according to object groups and their (sub-) objects is possible.

3.2 Object coding

Already in the early stages of the design phase of a project, it is important to define a project structure that includes consideration of the object-based way of thinking for the modelling that is suitable for the intended use-cases. Particularly regarding 4D and 5D functionality, it is also decisive to match the model structure and the individual objects, to the structure

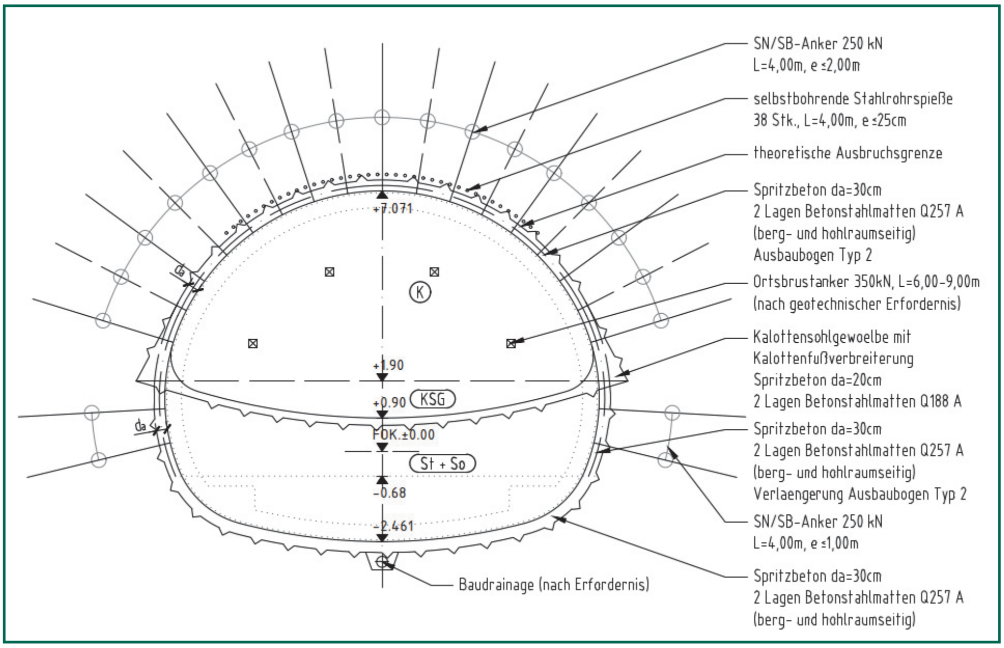

Figure 3.1
Traditional detail drawing of primary support

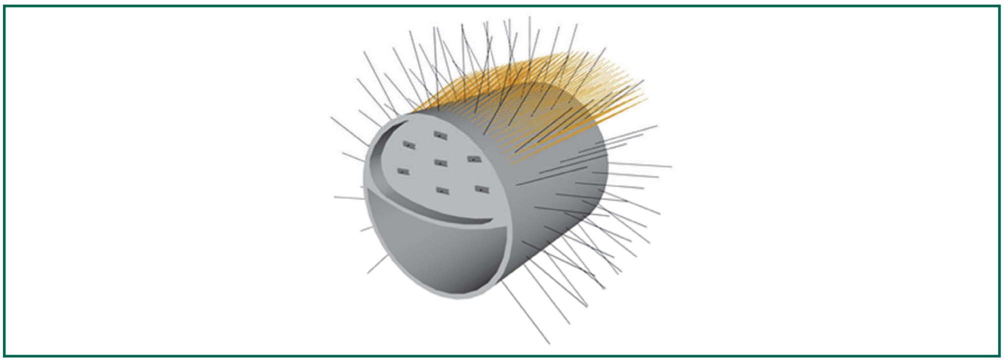

Figure 3.2
Illustration of primary support in the 3D model with (sub-) objects

Figure 3.3
Example illustration of the objects rock bolts, steel ribsand lining (top headinginvert/ shotcrete of the primary support in the 3D model

of the construction programme and the BOQ. So that the (sub-) objects defined in the object catalogue can be uniquely identified within a project design and thus enable a standardised and rule-based evaluation of the information in the model, it is necessary to assign these a unique coding.

This recommendation presents the results developed by the DAUB working group from the previously produced expert reports. In the formation of the object coding, care was taken that the systems already available on the market, like for example the StB Code of the BIM working group in special foundation engi-

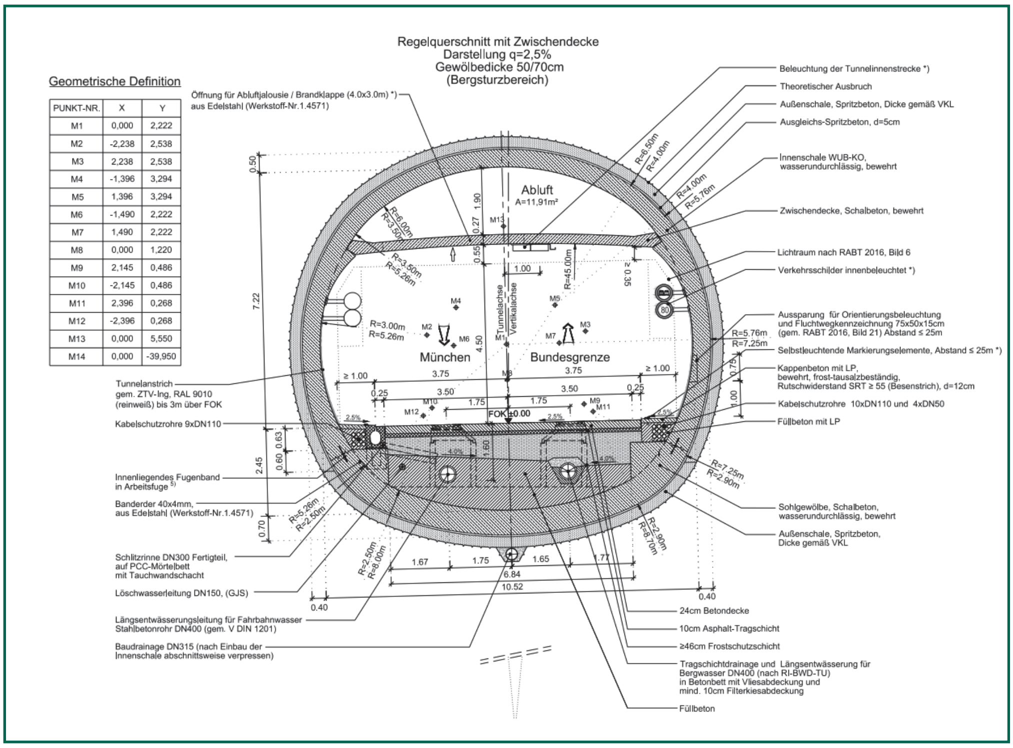

Figure 3.4
Traditional detail drawing of the permanent lining

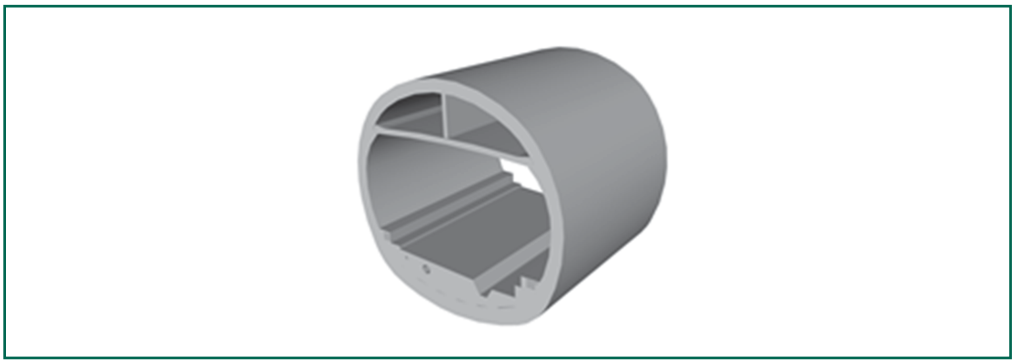

Figure 3.5
Illustration of the permanent lining in the 3D model with objects and sub-objects

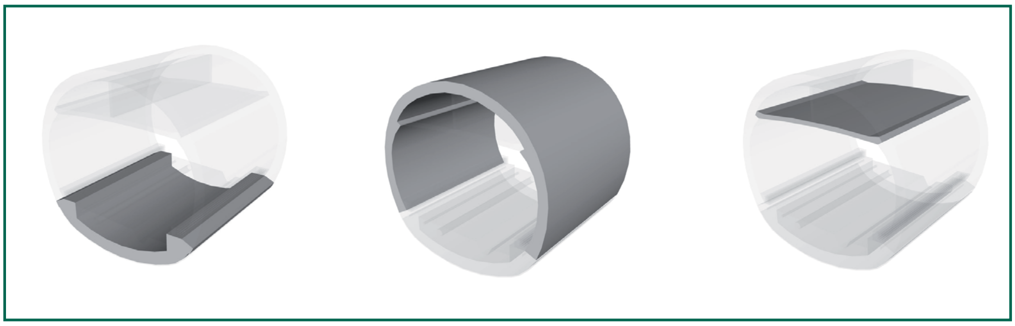

Figure 3.6
Example illustration of the objects invert, lining (concrete) and air duct slab of the permanent lining in the 3D model

neering, could be integrated. The application of this system is scalable due to its structure. Thus, the coding can be performed through the complete key or only a part of it. The diagram in **Figure 3.7** shows the structure of the system, which is explained in more detail below:

- The first four levels (Level 010 to 040, green) of the object catalogue (Client, Author, Project, Sub project) define the main project information and assign a responsible author to the modelled object.
- The second section (Level 050 to 080, blue) describes the type, functionality and location of the associated structure and also defines the corresponding specialist discipline.
- The third section (Level 090 to 120, red) deals with the actual objects. A unique definition of the modelled object is activated by collecting the objects or sub-objects into object groups and further localising them and making them identifiable through the assignment of numbers.
- The final section (Level 130 and 140, grey) serves to give the object a more detailed and final location definition, which can be used to localise it.

Each of these levels has numerical or alphanumerical values or rather abbreviations with a predefined number of digits, which together form the object code. Unassigned or missing information in the levels is filled with place holders (x). These place holders should also be used when levels do not have to be or cannot be filled. **Figure 3.8** provides an example to clarify this: the code structure thus follows the procedure „from coarse to fine".

This code should be automatically created by the relevant modelling program by input attributes. For this purpose, on the one hand, basic project information can be used when creating the model. On the other hand, entries can be made during the creation of the individual objects that are to be selected by lists or freely defined. The object catalogue already contains a large number of objects that can be used, however this list is not exhaustive and should in the future be further expanded based on the experience of the users.

Note for the English version:
Abbreviations representing the naming of the single levels and thus forming the object code are not translated into English.

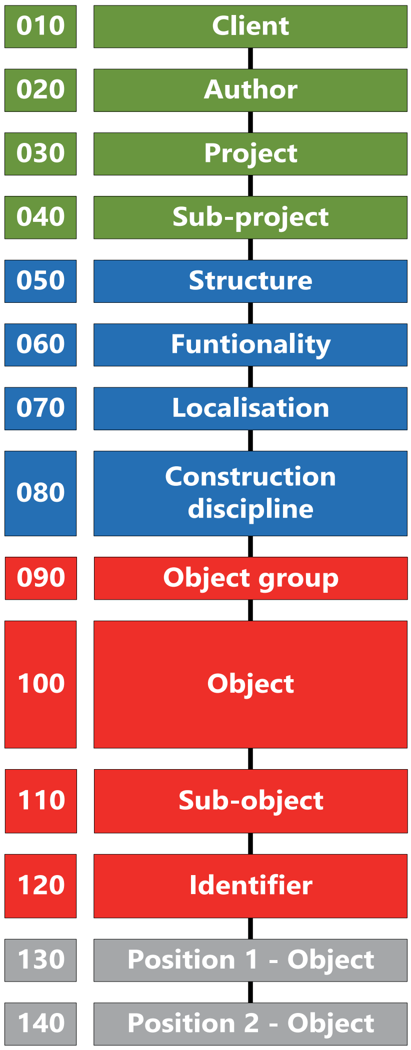

Figure 3.7
Object coding structure

3.2.1 Level 010: Client

In Level 010, information about the client is defined. Typically, there is only one client. On major projects, it is however possible that individual parts of the project have different clients. This Level enables assignment of the models to the various clients. One example for this would be the major project Stuttgart 21 (S21), where the Deutsche Bahn (DB) awarded the underground station and the Stuttgarter Straßenbahnen (SSB) awarded the Staatsgalerie tram stop.

Level 010: Client	
Default number of digits	5
Proposal for automated creation of the code segment	General project information in the model
Example	
Client	Deutsche Bahn
Code segment	DBxxx

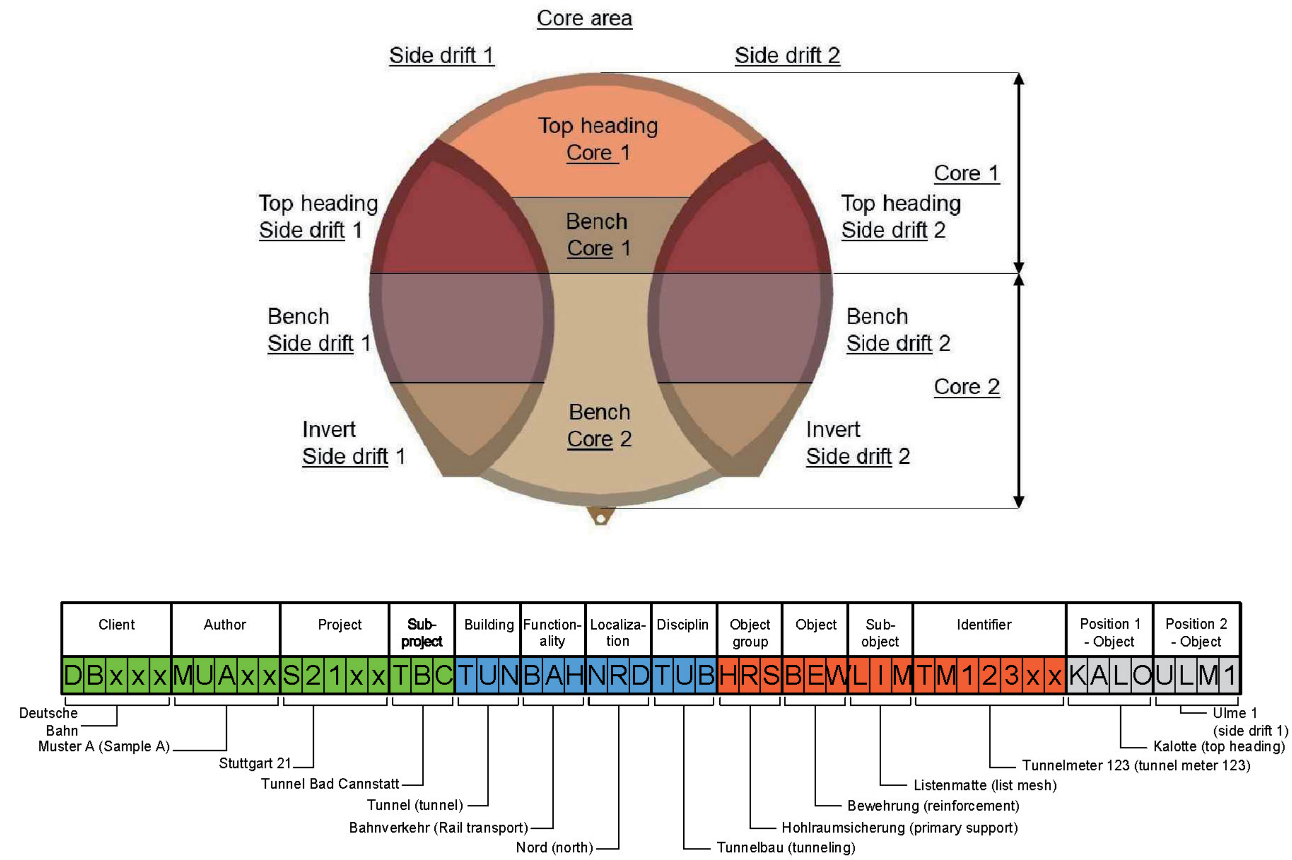

Figure 3.8 *Example of object coding*

3.2.2 Level 020: Autor

In order to clearly assign, monitor, and control the responsibility for model creation, the creator/author of the model is specified in level 020. The details here should be company-related and not personalised.

Level 020: Author	
Default number of digits	5
Proposal for automated creation of the code segment	General project information in the model
Example	
Author	Company Muster A
Code segment	MUAxx

3.2.3 Level 030: Project

The naming of the project can be done in level 30. Ideally, the abbreviation of the code should contain generally valid abbreviations, as shown in the example.

Level 030: Project	
Default number of digits	5
Proposal for automated creation of the code segment	General project information in the model
Example	
Project	Stuttgart 21
Code segment	S21xx

3.2.4 Level 040: Part project

In Level 040, the main project is split into the individual sub-projects or construction lots. For example, within this level the separate contracts „Zuführung Bad Cannstatt“ or „Zuführung Feuerbach“ can be named as sub-projects of the main project S21.

This Level is only provided for use when required, and for projects that are not divided this level should be filled with placeholders („xxx“).

Level 040: Part project	
Default number of digits	3
Proposal for automated creation of the code segment	general project information in the model
Example	
Part project	Tunnel Bad Cannstatt
Code segment	TBC

3.2.5 Level 050: Structure

In Level 050, the project or sub- project is further broken down. The breakdown is carried out in relation to the structures and covers all construction parts and disciplines. The object is thus assigned to a structure.

Level 050: Structure	
Default number of digits	3
Proposal for automated creation of the code segment	selection list and/or freely definable entry
Example	
Structure	tunnel
Code segment	TUN

3.2.6 Level 060: Functionality

Level 060 can be used to further specify the individual structures. The functionality of the structure can be described here if necessary. For example, a cavern could be assigned the functionality „Rail traffic“.

Level 060: Functionality	
Default number of digits	3
Proposal for automated creation of the code segment	selection list and/or freely definable entry
Example	
Functionality	rail traffic
Code segment	BAH

3.2.7 Level 070: Localisation

The process of localisation serves to further refine the defined location of the structure in order to perform a definite assignment of its location. For this purpose, the Level 070 is available.

Level 070: Localisation	
Default number of digits	3
Proposal for automated creation of the code segment	selection list and/or freely definable entry
Example	
Localisation	north
Code segment	NRD

3.2.8 Level 080: Construction discipline

Differentiation of the construction disciplines involved in underground construction is undertaken in Level 080. With this the object can also be assigned to an individual discipline model.

Level 080: Construction discipline	
Default number of digits	3
Proposal for automated creation of the code segment	selection list and/or freely definable entry
Example	
Construction discipline	tunnelling
Code segment	TUB

3.2.9 Level 090: Object group

The object group is a grouping of individual objects, which are assembled to form a completed product through various assembly processes. Through level 090, several objects (level 100) can be combined for better evaluation or visualization.

Level 090: Object group	
Default number of digits	3
Proposal for automated creation of the code segment	selection list and/or freely definable entry
Example	
Object group	excavation support
Code segment	HRS

3.2.10 Level 100: Object

An object, which is defined in Level 100, is equivalent to an element to be constructed or parts of the tunnel fit out (see **Section 2.5**). The level of geometrical and informative detailing of the object is essentially dependent on the project specifications. In order to make linking to the BOQ possible, it is recommended to use the payment unit of the BOQ item as a guideline.

The categorisation of the objects can also be performed with consideration of the construction schedule, according to how the project structure plan is organised, and which uses cases have been specified. The following Level 110 "Sub-object" serves for further refinement.

Level 100: Object	
Default number of digits	3
Proposal for automated creation of the code segment	selection list and/or freely definable entry
Example	
Object	reinforcement
Code segment	BEW

3.2.11 Level 110: Sub-object

A sub-object is the smallest element to be represented in the model. In this Level 110, objects within objects can be described, i.e. reinforcement in the permanent lining.

If Level 100 is sufficient for the unique description of objects, then this level remains „free" and is filled with the placeholder „xxx".

Level 110: Sub-object	
Default number of digits	3
Proposal for automated creation of the code segment	selection list and/or freely definable entry
Example	
Part object	list mesh
Code segment	LIM

3.2.12 Level 120: Identifier

The identifier, which can be defined in Level 120, serves to clearly differentiate between objects or to assign an object where there are many comparable objects, i.e. the block number of the inner concrete lining or the indication of the tunnel chainage. It also gives the spatial location along the tunnel. For the more precise differentiation of individual values, a combination of letters and numbers is helpful, e.g. „TM" as an abbreviation for tunnel metre and „1234" to state the chainage.

Level 120: Identifier	
Default number of digits	7
Proposal for automated creation of the code segment	selection list and/or freely definable entry
Example	
Identifier	Tunnel metre
Code segment	TM12345

3.2.13 Level 130: Position 1 – Object

The position of the object in the vertical sub-section is given in Level 130 in order to enable clearer identification of a specific position within the tunnel, e.g. top heading or bench.

Level 130: Position 1 – Object	
Default number of digits	4
Proposal for automated creation of the code segment	selection list and/or freely definable entry
Example	
Position 1 – Object	top heading
Code segment	KALO

3.2.14 Level 140: Position 2 – Object

Level 140 can be used to provide further detail of the horizontal position in the sub-section of a certain element within a model and enable a clearer identification of certain position, e.g. side wall 1, right or left, top or bottom.

Level 140: Position 2 – Object	
Default number of digits	4
Proposal for automated creation of the code segment	selection list and/or freely definable entry
Example	
Position 2 – Object	side wall 1
Code segment	ULM1

4 Properties and attributes

Appendix 3 contains a list with proposed properties and attributes for the (sub-) objects.

A property describes the characteristic of an object or sub-object and an attribute specifies this property. According to the standard DIN EN ISO 23386 each property may have one or more attributes, e.g. "value", "unit", "description in language N" or "naming in language N". The attributes available can be found in the standard mentioned above. Proposals for properties and the connected attributes "value range" and "unit" of the objects and/or subobjects are listed in **Appendix 3**.

In the time being the working group is basically revising the subject towards the use of a property data base. The release is planned for the 2nd Quarter in 2021.

Properties refer to objects or sub-objects, according to which element in the hierarchy is modelled at the lowest level (level 100 or 110). This is closely bound to the relevant use-case or the relevant level of detail (**Figure 4.1**). The following properties should be introduced for all objects and sub-objects:

- A property for each code segment (see **Section 3.2**) of the individual level
- A property for the object code assembled from the code segments
- The intended payment unit of the object or sub-object

In the course of the development of in-house object samples, it is recommended as a minimum to consider the properties of the object code and any further common properties of each object or sub-object.

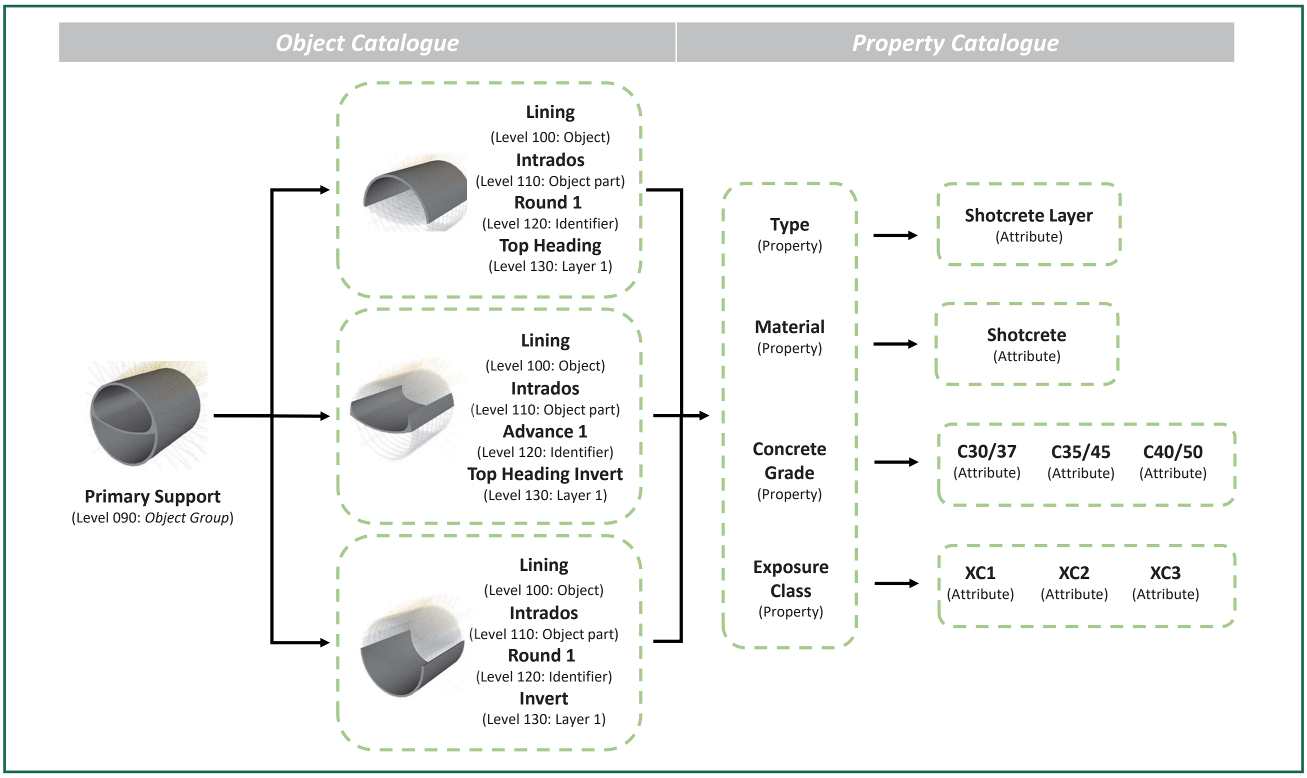

Figure 4.1 *Information in the object group primary support*

The objects or sub-objects listed in this document (see **Appendix 1**) describe, on the one hand, elements or equipment specific to underground construction, but also describe elements, which are often realised in connection with underground construction projects (e.g. jet grout block). The properties and attributes in **Appendix 3** are only listed for the specific tunnelling objects and sub-objects. This list is a draft and can serve as a sample for project specific selection or extension

5 Outlook

The objective of this first part of the Recommendation for Model Requirements was to create a uniform understanding for a project/model structure, to define an object catalogue with consistent descriptions for objects and state a basic structure for the corresponding properties and attributes.

Furthermore, some subjects have however not been conclusively discussed and defined. For this purpose, supplementary requirements (Model requirements – Part 2 et seqq.) are to be prepared. These should deal with the following subjects:

- Model types
- Granularity
- Dealing with or consideration of pre-cambering, overbreak or tolerances in models for underground construction
- Use-cases and their properties
- Interoperability, data exchange
- Coordinate systems
- Alignment dependencies
- Model-/information-transfer scenarios
- …

The workings of the DAUB working group „BIM in Tunnelling" are not final and still have to be proved in practice. Experience, which will be gained in further processing according to this recommendation, will be integrated in further supplements or revisions and published.

In the course of the further development of BIM in tunnelling, it will also be important to develop a standardised, object- and model-based **Bill of Quantities** for underground construction. It will be target-oriented and beneficial to all project parties if the models are already created during the design phase and made available to bidders and potential contractors as a tender model in the tendering phase. The involvement of all parties in early project phases may also be redefined by the client. These recommendations should serve as a basis for this.

The subject of **Geological modelling** also demands further specification since this discipline is significant for the sensible use of BIM in underground construction. The coding of the objects in the ground model should match the system presented here in order to ensure continuous use of the model, especially with regard to model-based payment and analysis. Collaborative management is the key to overcoming the challenges resulting from contract arrangements when it comes to geological risk allocation. It also has to be said here that the ground model should primarily reflect the geological report and the level of detailing can only be as accurate as the site investigations it is based on. The use of a ground model will however serve to improve project understanding and the evaluation of performance, thus, in turn also reduce risk. This application is to be seen as interdisciplinary and covers various project areas. Therefore, on complex projects, it cannot just be defined by the underground construction. The technical position paper „BIM im Spezialtiefbau" (BIM in special foundation engineering) of the German building industry association already covers the subjects of digital soil models and digital terrain models. Due to the current limitation regarding the practicality of 3D digital geological modelling, closer attention should definitely be paid to this specialised area in the future in order to be able to cover this use-case as well.

Activities of building SMART International (bSI) are currently underway in the Infrastructure Room (IFC Tunnel). This may entail a revision of the classes of the neutral data format **IFC (Industry Foundation Classes)** in order to be able to represent and exchange all objects and information for the special needs of tunnelling.

In order that the system developed within this recommendation can be put into use, the object coding and the object catalogue including the proposed properties and attributes will have to be integrated into the software landscape. For this purpose, coordinating activities are needed among all those involved including the software suppliers.

All in all, it can be stated that this supplement to the DAUB recommendation „BIM in Tunnelling" represents the next major step towards standardisation of this design method in underground construction. The publication of further parts of the model requirements, as described above, will ensure even greater clarity and understanding for all parties. This will further advance digitalisation in construction industry and ensure that clients and contractors can work collaboratively in a spirit of partnership from the very beginning to ensure the success of the project. ■

6 Glossary

3D model	Three-dimensional model of a structure containing physical, geometrical and functional attributes
4D model	3D model, which is linked with the construction schedule or the construction activities through the component time.
5D model	Extension of the 4D model to include cost planning
AIA	Employer Information Requirements (EIR); contract document, which specifies the information requirements of the client for tendering in order to lay down the framework conditions for BIM application
Attribute	Attributes specify the features of an object (according to DIN EN ISO 23386)
Tender model	Model, which is made available by the client to all bidders in the tendering process
Use-case	Special application using BIM methodology derived from the BIM aims
BEP	BIM execution plan; contract document, which explains the bidder's plan for application of BIM and is cyclically developed during the course of the project, the level of detailing (LoI, LoG and LoD) is also laid down here
Ground model	Model with representation of the geological situation below ground
BIM	Building Information Modelling; BIM describes a cooperative working methodology based on the use of BIM models, which consistently record, administer the relevant information and data of a structure over its lifecycle and permit transparent communication and exchange between the contract parties or handover for further processing
bSI	building SMART International; an international non-governmental non-profit organisation; it defines the exchange format Industry Foundation Classes for BIM data exchange in construction
Code	Unique definition of an object through the assignment of numerical and alphanumerical attributes; the overall code consists of the individual code segments
Code segment	Part of the overall code, which defines the individual levels of the object catalogue proposed here
DACH	Acronym for Germany (D), Austria (A) and Switzerland (CH)
Level of detail	Describes the information content of digital 3D models (Level of Detail = LoD)
Geo-referenced	Spatial assignment of an object in a coordinate system
Construction discipline	In construction, this covers the works in a specialised field
Granularity	Level of detail of the geometrical and semantics information
IFC	Industry Foundation Classes; manufacturer-independent, open, standardised and object-oriented data format for exchange of models
Interoperability	Compatibility of software systems with regard to data exchange without loss
BOQ	Bill of quantities; tabular listing of work items to define the works to be undertaken under a contract

Modelling guideline	Defines the framework conditions for the creation of models to be observed in an organisation or on a project
Model structure	Definition of the structure of the individual part models and their relationship (Coordination model)
PSP	Project structure plan; categorises the overall extent of works in a project into partial items and work packages

Appendix 1 Object catalogue

Appendix 2 Examples of object coding

Appendix 3 Examples of properties and attributes

Appendix 3.1 Properties and attributes of object group Temporary support
Appendix 3.2 Properties and attributes of object group – permanent lining – concrete works
Appendix 3.2 Properties and attributes of object group Excavation advance

Appendix 4 Examples of visualisation

The Appendixes listed above are available for download as compressed archives.