CAD manual

Banedanmark

BANEDANMARK

CAD Manual
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Revision log

Revision date	Version	Responsible	Section	Description
2015-10-07	01.00	SBAC SHSH XAMBI XLESO	Whole document	First final edition
2016-04-18	01.01	XAMBI XLESO	Section 3.2.3, 3.2.4, 3.2.5, 3.2.6	BTR added to file naming. Punctuation mark changed to dash (-)
2020-02-15	02.00	SBAC SRDL LTKT AKDJ POIV	Whole document	Description, usage and level of detail for models moved to appendix 3. The whole document updated according to results from BIM Infra.dk according to BIM level 2.
2022-05-25	02.01	SRDL LTKT JFLC	Major changes: 2.3, 3.2, 3.3, 4.1, 4.6.1 and App 1 Minor changes: Whole document	File types, versioning, model block and appendix 1 have been changed. New requirements for quantities have been added. The whole 4.1 section has been updated because of moving from BIM infra to DiKon requirements, and appendix 3 has been dropped. And minor changes have been made throughout the whole document.

1 Information

Main reason for this update, is implementation of "DiKon anlægsdelsspecifikationer", which will replace the use of Appendix 3.
As a result, there has been consequential amendments to the rest of the document.

The present CAD manual describes common standards, structure, documentation and exchange formats while working on the projects for Banedanmark. Each project defines which sections of the CAD manual are relevant for the deliveries in the specific project in the Information and Communication Technology Cooperation Specification, (ICT/IKT Specification).

The CAD manual is an extension to Banedanmark's Requirements for Technical Documentation "Krav til Teknisk Dokumentation". The valid document in Danish can be found at Banedanmark's Website www.bane.dk.

This CAD manual establishes the general guidelines for CAD work at Banedanmark. The guidelines must be used by all parties to ensure a structured and consistent preparation of CAD data to benefit all parties involved.

The current version of the CAD manual is available at www.bane.dk and will be continually updated.

In case of disagreement between the present CAD manual and the ICT/IKT Specification for each contract, the ICT/IKT Specification is governing.

1.1 Different contract types

Banedanmark operates with different contract types. The detailing level of Banedanmark's deliveries and the requirements for deliveries to Banedanmark will differ depending on the type of contract. This CAD manual applies to all the different contract types within the projects. The ICT/IKT Specification for each contract will include further relevant information and contractual requirements.

1.1.1 Consultancy Contract

In Consultancy Contracts Banedanmark engages consultants to perform the different stages of design including Preparatory works, Conceptual design, Detailed design, preparation of the tender material and preparation of as-built data. Depending on the tender strategy, the tender material can have different levels of development. The requirements for deliveries in different phases are defined in ICT/IKT Specification for the specific project.

1.1.2 General Contract

In General Contracts Banedanmark delivers tender documents as Detailed Design and engages a contractor to carry out the design accordingly and deliver the required data back to Banedanmark. The consultants who have been involved in performing the tender material bear the responsibility for controlling and delivering the as-built models, drawings and documentation.

1.1.3 Design & Build Contract

In design & build contracts the contractor is engaged to carry out both the design of a given structure and the construction of it. Banedanmark delivers the extension limits of the structure. The contractor bears the responsibility for preparing further design, construction and as-built models, drawings and documentation.

1.2 CAD organization and responsibility

Each party as well as Banedanmark must appoint a CAD coordinator. Information about the CAD coordinators different assignments are to be found in the ICT/IKT Specification.

1.3 CAD server

In projects with regular use of CAD data, Banedanmark's ProjectWise must be used for preparing, updating, exchange and delivery of CAD data.

Further details are to be found in each project's ICT/IKT Specification.

All CAD files must be updated regularly and be available on the CAD server, always. It must be clear how far in the design process the model is, either by list or by states in a workflow.

1.4 Resource Files

A set of resource files are available on www.bane.dk and on ProjectWise. The resource files are to be used when working on Banedanmark's projects.

2 Basis for CAD production

2.1 File and folder structure

If ProjectWise is chosen as the CAD server, the folder structure defined by Banedanmark must be used. Metadata defined in ProjectWise must be filled in, by adding information in model- and drawing blocks and if necessary, directly in ProjectWise.

If another common exchange server is chosen as the CAD server, Banedanmark defines the folder structure and belonging metadata. This structure must be followed by all parties. Changes are only to be made after agreement with Banedanmark's CAD coordinator.

2.2 Coordinate system

Referring to the Danish rail norms (Banenorm) the horizontal coordinate system KP2000 and the vertical coordinate system (elevation) system DVR 90 must be used.

All plan files and 3D models shall comply with the project's elevation and coordinate system. When files are received from other parties, and data are not placed in the project's elevation and coordinate system, the files must be transformed before use.

An exception to this is GIS data that must be converted to UTM32. See Section 8.2.4.

2.2.1 Unit system

All model files must use the same metric unit system in all 3 dimensions. Work shall be carried out in 1:1.
In MicroStation files 1 drawing unit/master unit = 1 m and subunits shall be mm with an accuracy of 0.1 mm.

If there is a need to use millimetres as the master unit, the file must cover the same "Working Area" as defined in the meter file.

The unit system is defined in the templates delivered by Banedanmark, which must be used by all parties.

2.3 Model block

All model files must have a model block containing Tags/Attributes. Each supplier must place its logo or name in the block, on the right of the BDK

logo, so that the owner of the file can be easily identified. The model block must be in placed in; 470000, 6100000, 0 for projects working in KP2000S and 140000,6100000, 0 for projects working in KP2000J.
The model block is found by default in the template/seed file but can also be found in the cell library. The tags/attributes in the model block must be kept as they are named. Changes are not permitted.

First line in *Subject* must be the same on all models in a project.
Second line must be a short of description what the model is showing.
Internal reference is the project number.
Scale must always be set to 1:1 on model files
Date is the date the model has been created, and the *Date* in revision log is then it was last updated.
Initials is who has created the file, and *Initials* in revision log is who has last updated the file.
Revision description is optional and can include a small description of what has been updated since last.

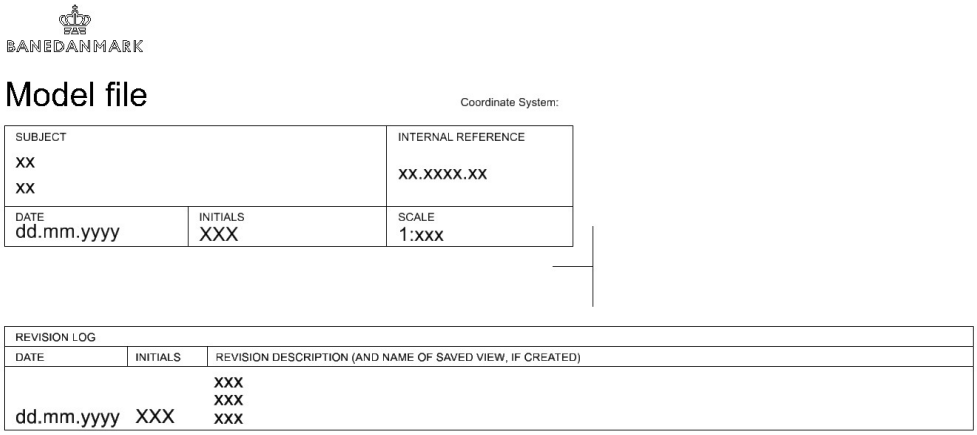

Figure 2.3-1 Model block

2.4 Title block and drawing frame

2.4.1 Banedanmark's title block

Banedanmark's title block is to be used for all drawings. The current version can be found at www.bane.dk or from the resource folder on ProjectWise.
The title block contains tags/attributes, which shall be used by all parties and must be kept as they are named. Changes are not permitted.

References:

- Layout and different fields in the title block: "Krav til Teknisk Dokumentation
- Revisions and versions management: "Krav til Teknisk Dokumentation"
- Drawing numbers: "Krav til Teknisk Dokumentation".

2.4.2 Drawing frames

Drawings shall be provided with a highlighted border so the top, bottom and right margins are 10 mm and left margin 25 mm. Besides standard ISO A formats (A0 - A4) A-frames must be used. A-frames contain a number of folds in multiples of 210 mm wide and 297 mm high.

See also DS102 and DS103 for instructions.

Frames can be found at ProjectWise or www.bane.dk as a cell library for MicroStation.

2.5 Drawing layout

Drawings must consist of a maximum 8 A4 drawing frames wide and 2 A4 drawing frames in height.

The title block is to be placed in the bottom right corner of the drawing frame.

The north arrow is placed inside the drawing field in the upper right corner.

Plan drawings must be rotated so the railway stationing increases from left to right. Exceptions to this rule are crossing roads where a rotation is needed so that the stationing of the roads is the main focus.

The scale symbol is placed on relevant drawings in the bottom left corner. The symbol is to be used on large scale drawings (1:40000 – 1:500).

North arrow and examples of scale and other relevant symbols to be used on drawings can be found in ProjectWise or at www.bane.dk.

In addition to the title block, the fold containing the title block must only be used for the revision log, notes, legend and key map.

The map key must be used on relevant plan drawings. The frame for the map key is included in the title block cell in a separate layer/level. This level must be turned on and the frame must be filled with the relevant map key as well as empty rectangles indicating all drawing frames along the specific discipline of the project. The current drawing is marked by filling in the corresponding rectangle. Location names must be added on the map key for localization.

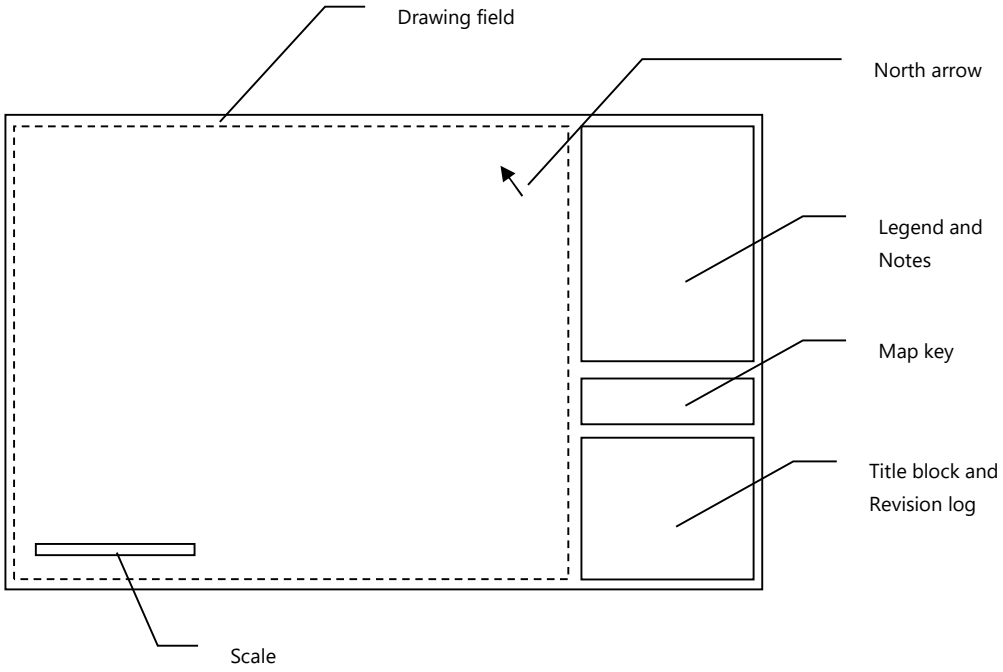

Figure 2.5-1: Principle for drawing layout.

2.6 Text and dimensioning

The text on drawings must be written in upper and lowercase. When specifying decimal separation (text and measurements) commas must be used, e.g. “9,65”. If a 1000 delimiter is required, it must be indicated by full stops/period, e.g. “120.650,00”. Stationing for roads and tracks must be indicated with . for 1000 delimiter, e.g. “60.000”.

On drawings in general, text height is 2,5 mm for descriptive text, measurements and text for illustrations, and 3,5 mm for headlines and specification of location. In drawings with a high level of detail, a text height of 2,0 and 1,8 mm may be used.

Superscripts such as headings below illustrations should be written with an underlined text, height of 3.5 mm, block letters and below the illustration e.g. PLAN, 1:100, SECTION B, 1:20, DETAIL 2, 1:5.
Align text with the illustration’s left side.

A text that is logically coherent may not consist of several text sections.

Text relating to geometry, stationing etc. must be placed either in the 3D model file on separate layers defined by the standard layer structure or in a separate 2D file. If the text for constructions etc. needs to be placed in the drawing file, it must be placed in the drawing file's model environment.

Use the True Type font Arial as the default text font.

Symbol fonts are often used in files received from, for example, surveyors. As

these fonts are difficult to convert to other CAD formats, it is recommended that cells/blocks are used instead of fonts, to show symbols. If symbol fonts are necessary, these shall be uploaded to the project server together with CAD files.

It is recommended that dimensioning is associative. Drawing-related changes must always be executed by changing the geometry first and then changing the dimension. Amendments must never be made to the dimension text alone, instead of revising the geometry.

2.7 Layer/levels

Layer/Level structures defined by "Det Digitale Anlæg (DDA)"[1], that defines the different layers/levels of each discipline, are to be used. The level libraries for the most used disciplines are to be found on www.biminfra.dk and on ProjectWise. Where the layer/level structure for a discipline is not defined by DDA, the latest version of Molio publication C211 Level structure 2015 can be used. If there are areas of the project without a defined level structure, the following coding principles are to be used for naming the necessary levels:

A	**F**	_	**T**	_	**U**	**U**	**U**	_	**E**	**E**	**E**	**E**	**E**	_	**Z...**

Where:
A is the Responsibility Code
F is the Discipline
T is the Theme
U is the Sub-theme
E is the Element
Z... is the unlimited number of capital and lower-case letters for other sub-elements.

Any suggestions for new layers/levels must be confirmed by Banedanmark's CAD Coordinator.

[1] "Det Digitale Anlæg" has changed name to "BIM Anlægsforum", but the layer/level structure has kept it's name and structure. See also chapter 9.2 Glossary.

3 Structuring of CAD files

3.1 Geometry

Constructions and technical elements are designed as 2D/3D geometry and/or 2D/3D construction objects and are placed in the model files to which they belong in terms of theme and responsibility. Geometries/elements must be named in the same way in models and on drawings, so they are easy to identify and find.

3.1.1 Discipline data

When using discipline specific applications to design the models, a number of external data files might be generated. This data does not have a graphical interface by itself, but can be displayed as graphics in a DGN- or DWG-file. These data files are called discipline data and are the basis for generating the 3D models, 2D extractions and quantities.

3.1.2 2D geometry

2D geometry is either:

- extractions of discipline data (e.g. cross sections)
- extraction of 3D geometry
- supplements to extractions from 3D models (e.g. patterns and symbols)
- manually created 2D geometry (e.g. details)

3.1.3 3D geometry

3D geometry is either:

- graphically displayed 3D discipline data
- 3D elements modelled directly

3.2 File types and naming

The different types of CAD files are defined as described below. When naming files, none of the Danish characters ”Æ, Ø, Å, æ, ø, å” are permitted. Similarly, file names may not contain full-stops, commas, spaces or special characters other than underscore "_" or hyphen "-".

File type	Description
Template /Seed files	Templates for all files generated in the project.
Discipline data files	From design tools in relevant disciplines.
Model files	For creating, processing and storing the design.
Drawing files	For creating and maintaining drawing layouts, and exchange of drawing files in CAD format.
Assembly models	For QA of consistency, quantities etc.
Notation files	For frames, folder markers and notes.
Digital plots	For documentation of drawings.
Survey data	Surveys of conditions, such as land surveying, Lidar scan, photogrammetry or orthophotos for comparison with design.

Table 3.2-1 File types

Appendix 1 contains principles for naming the individual files.

3.2.1 Template/seed files

Template files (seed files in Bentley applications) are to be used when generating new files. Templates/seed files delivered from Banedanmark are available as MicroStation and AutoCAD files. The 3D MicroStation seed file and AutoCAD template file contains colour table, dimension styles, text styles, and model block.

3.2.2 Discipline data files

Applications generating discipline data produce different types of file formats. Discipline data files are the files that contain these data.

Discipline data files are typically used to generate model files for terrain, utilities, embankments, alignment (plan and profile) and cross sections, but might be used for other kinds of output, for example regarding quantities and machine control. When using compatible applications, it is a benefit to exchange the data files in the native file format together with the relevant model files. Otherwise, the files must be exchanged in LandXML format together with the outputs in DWG/DGN. Regarding file formats, please see chapter 6.2.

This CAD manual defines principles for naming files with alignments and surfaces, which can be exchanged between the different parties. Appendix 1 has defined the naming convention.

Banedanmark use Bentley products and are able to receive and control discipline data in Bentley ALG- and DTM-formats. When using other applications than Bentley products for generating alignments and surfaces,

the files must be exchanged in LandXML format together with the outputs in DWG/DGN, supplemented with geometry reports on demand. The LandXML format from other applications must be tested and approved by Banedanmark by upstart of the project.

Point Clouds must be exchanged in LAS or LAZ formats. Banedanmark use Bentley products and are also able to receive POD format.

Whereever IFC formats are applicable, the data must be used for exchange and delivery to Banedanmark as supplement to the proprietary formats. In this case the requirement will be specified in the ICT/IKT Specification.

3.2.3 Model files

A model file contains a discipline-specific collection of 2D/3D geometry and/or construction objects. All amendments to the project are made in the model files.

Each area of responsibility (discipline) shall establish and maintain its own model files. No amendments may be made in another discipline's model files.

Supplementary models are gathered in drawing files. At the same time, one model file can be part of several different drawing files and can also be shown in different scales.

Appendix 1 has defined the naming convention.

The revisions of model files are tracked via the revision log in the model block as well as the metadata on ProjectWise. Version and revision naming are not included in the actual CAD file name.

3.2.4 Drawing files

Drawing files are used for setting up and maintaining drawing layouts. Drawing files can either be delivered with references or as merged drawings.
Drawings with references:
Supplementary models must be referenced into drawing files and are not allowed to be merged/bound, into the master file. At the same time, one model file can be referenced into several different drawing files and can also be shown in different scales. The model files used to generate the drawings must be based on 3D models or 2D extractions from the 3D models with supplementary information.
Merged drawings:
Merged drawings has all the same characteristics as a drawing file with references except that all references are merged into the drawing.

The drawing files contains:

- Frame

- Title block
- References to model files

In addition, the drawing files may include:

- Notes
- Legend
- Map Key
- Scale signature
- North arrow (if plan view)
- Copyright label when using basis or cadastral maps, if applicable.

Regarding the layout of drawings see figure 2.5-1.

The drawing number must always be identical with the name of the associated drawing file. Revision management of drawing files is carried out by filling in revision fields in the title block as well as using revision clouds around the revised areas in the drawing file.

The convention for naming and numbering drawing files must follow Banedanmark's Requirements for Technical Documentation (Krav til Teknisk Dokumentation i Banedanmark). The valid document in Danish can be found at www.bane.dk.

For generating and naming of the multipage drawings see "Krav til Teknisk Dokumentation".

3.2.5 Assembly models

An assembly model is a model containing references to model files and are meant as a service for other parties to tell which references are useful. Several assembly models can be created to suit different purposes, e.g. clash detection and visualization.

The assembly model contains no design geometry but can contain other information such as Saved Views and collision control reports.

Each party is responsible for its own assembly models and their maintenance. An example is the assembly model for all designed roads within the contract area or specific locality.

Appendix 1 has defined the naming convention.

3.2.6 Notation files

Notation files contain the cells/blocks used to supply the models and drawings with information, e.g. symbols and patterns, drawing frames, Title blocks, notes, etc. There are no requirements for naming notation files.

3.2.7 Digital plots

Digital plots are plots of drawing files in formats such as PDF, TIFF, etc. and are used as a basis for, and exchange of, the paper prints digitally. Digital plots are also used for documentation. All PDF Digital plots must be Georeferenced.

Digital plots are named identically with the name of the drawing file.

3.2.8 Survey Data

Survey Data is 3D data in forms of points, break lines or surfaces which have been generated based on different measurement types, e.g.: land surveying, Lidar scanning (terrestrial, airborne or mobile), photogrammetry and orthophoto.
Some of the most common outputs of survey data are orthophotos, point clouds and text files with point data.

The different types of survey methods have different kinds of precision.
It is very important to keep in mind that survey data has one uncertainty in the points where the measurements have been made and a completely different uncertainty in between where the data is interpolated.

Survey data collected for Banedanmark, must follow the naming requirement of the newest version of "Banenorm BN2-94". Survey data drawn out in model files, must follow the naming requirement for model files in section 3.2.3.

3.3 Version and revision management

Amendments to the project will lead to changes in several different file types. The table below provides an overview of how amendments are handled in different file types.

File type	Method
Model file	Newest update is managed in the log beneath the model block. The file name remains the same.
Drawing file	Version and revisions are managed in the title block and documented in the log. The file name remains the same.
Digital plot	Version and revisions are managed as in drawing files.

Table 3.3-1: Version and revision management

Drawings and digital plots generated before tender, can use capital letters for version e.g. 00.0A ("Krav til Teknisk documentation" makes a recommendation for 00.00A but many systems can only work with 5 letters). The first version of the tender drawings must be named 00.01, if any revision is made after tender the revision number goes up e.g. 00.02. The procedure for revision management after tender is described in "Krav til Teknisk documentation" section 3.5.

3.4 Information in models

To standardize and communicate the level of information need in different phases of projects, the Danish standard for "Level of Development" LOD-DK is chosen. The standard indicates the level of geometry and level of information in the designed models, as specified through the development of specific object types. This specification is a Danish adaptation of the American standard LOD, developed by BIM Forum. It is chosen to include certain aspects of the American LOD standard that are not in the LOD-DK standard. An example being another level LOD100. The standard consists of three parts:

- Level of Geometry (LOG), the graphical detail of the geometry in the model.
- Level of Information (LOI), the content and validity of information included in the model.
- Level of Reliability (LOR), the correctness of the model and how reliable the LOG and LOI are.

The information in models consist of both graphic and nongraphic information. A general specification of the LOD levels has been made to support the individual description of each discipline model. The specific description of each model, or of object types contained within models, will always overrule the general specification.

The LOD levels are not fixed to any specific project phase, resulting in a flexible system where any LOD can be chosen to any given project phase.

3.5 Reference technology

Information is generated in one file only.

If there is a need of information from another model, reference file technology must be used.

All drawing files must use reference file technology, thereby gathering information from supplementary model files.

3.6 Modelling discipline

Continuous lines must not consist of several line segments and there should be no remnants of the old congruent lines. Do not place several identical entities on top of each other.

The content of the model files shall be placed correctly in relation to the agreed project coordinate system. The models shall be modelled in exact dimensions corresponding to the physical elements.

The graphics in the designed model files should be divided into project agreed layers/levels in a manner that will allow other parties to turn off elements that are irrelevant to them (e.g. utility pipes on a different level than texts and dimensions relating to them). Model files must only contain relevant elements and layers/levels.

Shapes (types: shape, complex shape, polyline and ellipse) shall, for the sake of further processing, always be executed as closed elements. Where lines define a delimited area, the lines should be drawn as a closed shape (continuous line without cessation or duplication).

Shapes that are to be plotted as filled shapes (with a raster pattern or with a colour) must have the fill and the border placed on separate layers/levels, so that each part can stand alone.

Designed model files should be of an appropriate size, depending on the chosen application and content of the files. A maximum of 20 MB will be usable for most types of files. Terrain models may generate larger files eg. 50 MB. It is recommended that these size limits are agreed on during the design process.

Designed model files must be divided in disciplines relevant to the project, and only contain elements of that discipline.

Designed model files must only contain one model environment and one layout environment.

4 Use of models

3D models and discipline data are used for multiple purposes and the area requires a great deal of coordination and exchange to get optimal benefit of the information.

The models and discipline data can be used in the following processes:

- Drawing production – preparation of drawings
- Simulation – technical analyses
- Consistency control – geometrical checks, clash detection, interfaces
- Visualization – project reviews/coordination and presentation
- Data extracts – quality assurance and quantities
- Exchange

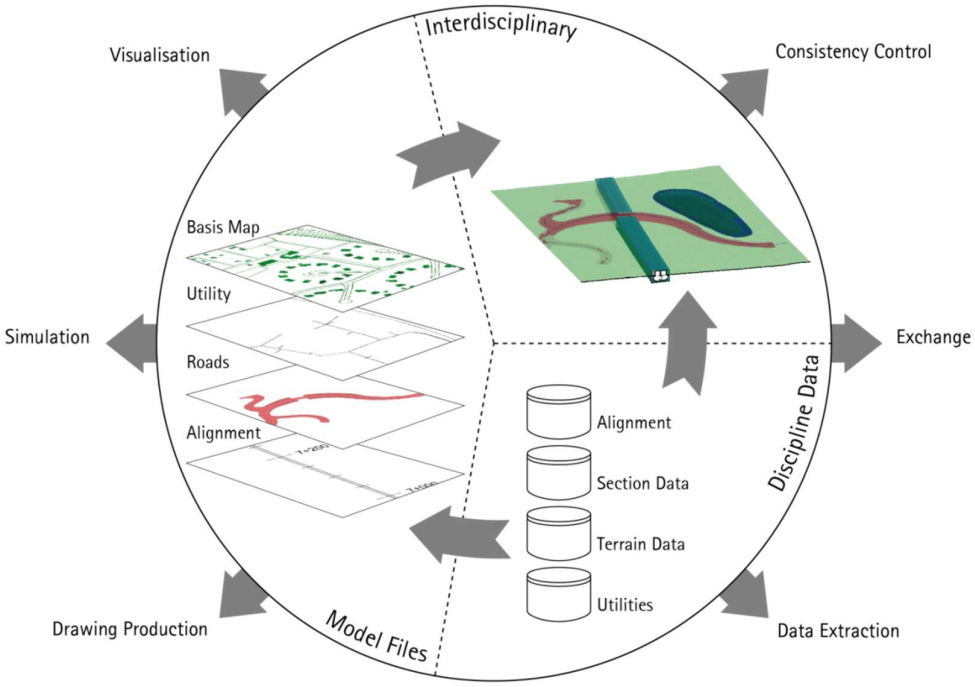

Figure 4-1: Use of models.

4.1 Models and discipline data

In this section, general requirements for models and discipline data to be generated within a Banedanmark project is registered. Project specific details and requirements regarding information- and geometrical levels can be found in the ICT/IKT Specification for the specific project.

Basis models:
The basis models show the existing conditions. These will be used during the whole design and construction phase with the necessary updates. The extent of the models necessary for different types of projects, can vary. The requirements will be clarified in the ICT/IKT Specification.

Basis models must be delivered in DGN or DWG and DTM or XML. . Where applicable, the models and discipline data must be delivered in IFC format too. The requirement will be defined further in the ICT/IKT Specification for the project.

Designed Models:
The designed models show the future and temporary conditions. These can be updated many times within the project, and it is therefore very important that it is communicated how far in the design process the model is, either by list or by states in a workflow.
Designed models must be delivered in DGN or DWG and DTM or XML. The models must at least be split up into a file for each discipline, see appendix 1, and must be split to match the relevant project area e.g. the bridges need to be delivered as at least one file per bridge. Furthermore, the models must be split into files in such a way that the naming requirements can be fulfilled.

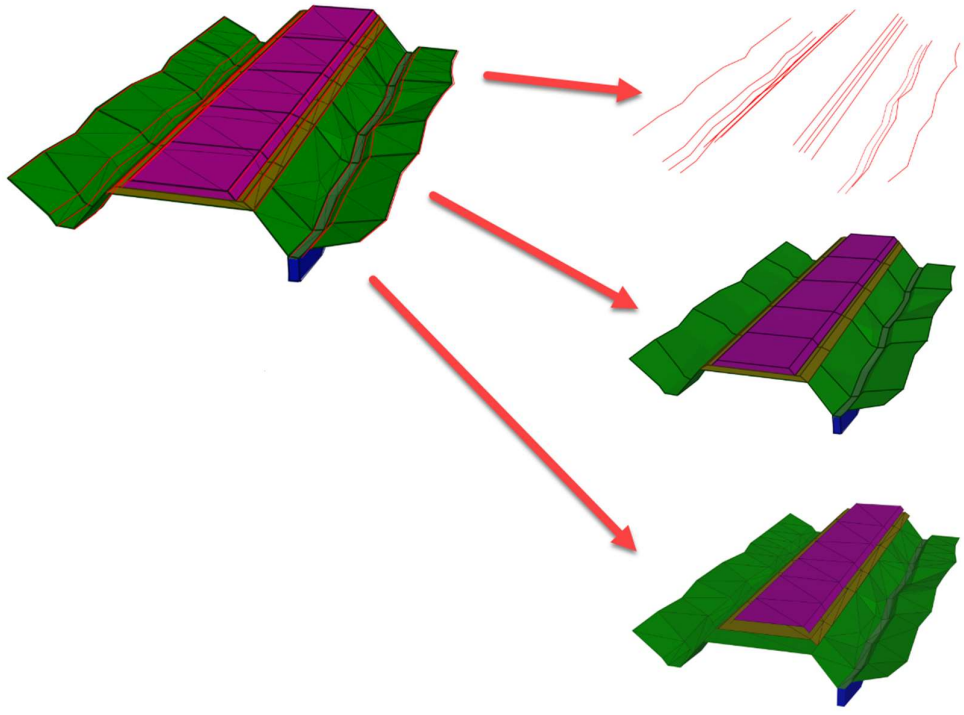

Figure 4-2: Splitting a civil model into three separate models. Done here with a corridor.

Designed civil model that are associated with corridor design, excavation, embankment and other similar, must consist of data that can be used for quantity, identification of objects and setting out data, for future comparison of designed and constructed civil work.
Civil models must have the functionality to separate the objects into minimum 3 sets of data, into separatable models for each, that are associated to each other.
Component civil model consist of solids/components for each object in the 3D model. Content will include ballast, subballast, drainage etc in identifiable unique layer structure. It is a requirement that cut and fill quantity is modelled as closed solids since this needs to be identified and objectified for 4D planning.
Surface civil models are triangulated surfaces used for construction and quantity comparison between parties. The triangulated civil models must uniquely identify each excavation and embankment work. Triangulated model must be based on feature civil model.
Feature civil model consist of breaklines/features uniquely identifiable, layered, and associated to component- and surface civil models. Feature civil model can be used for reconstruction and reorganising of features in the preparation of additional calculations and planned setting out data.

Rail corridor must include ballast, topballast 7 cm under sleepers, subballast, formation level, embankments and drainage.

All Models:
All singular, separable, and selectable components, that can be geometrically modelled as solid objects with a set of defined and accurate boundaries, must be modelled and represented as such and thereby not as surfaces, curves, lines or points, or any discontinuous combination thereof.

The above requirement means that any object which does not explicitly require the discipline geometry to be modelled as surfaces, must be made as logically coherent solid objects representing the final form as the three-dimensional external borders of the object. The solid objects must also allow attribution of discipline data associated with the object(s) and user selection by object types or instances. As well as data attribution, selection, sorting and filtering, extraction of the contained properties for other purposes as decided by the client organization, must be possible with no additional design work.

In addition, the objects in the designed models must be useable in the setting out of structures during construction. In this context, the demand to object modelling of structures does not only include loadbearing components but all geometrical forms.

In the case of singular, separate components or object types within designed models not being modellable or representable as solid objects with a set of defined and accurate boundaries, the deviation from this

requirement must be documented and approved by the client's CAD coordinator.

In models containing surfaces (e.g. terrain models, basins, road surfaces), each layer must be represented as a 3D surface including the break lines and points used to construct the model. Surfaces and the belonging break lines must be placed in separate layers. It must be possible to extract correct quantities including volumes from the surfaces either directly from the CAD format or by delivering the discipline data used to generate the surface.

Models including earthwork design must include the necessary information for setting out and for machine control. Each surface must be delivered in a separate file, as either DTM or LandXML.

When several contracts are involved in modelling different parts of the same project, the interfaces between them must be clearly defined and each contract bears the responsibility for designing and updating their own models according to the interface agreements. Section 6 describes the exchange process.

4.2 Drawing production

Data used in drawing production must be derived directly from the 3D models, supplied with necessary 2D information in all phases of the project as well as in the as-built documentation.

General requirements for content and layout of drawings are described in section 2.5.

4.3 Simulation

Simulations can be performed based on both 2D and 3D models within one or more disciplines.

For simulation purposes, each individual party can create its own simulation models, if necessary supplemented by input from other relevant disciplines.

Each party is responsible for implementing amendments, demonstrated in simulation tests. Amendments outside the discipline of the party performing the simulation must be coordinated with the relevant parties.

4.4 Consistency control

Consistency control must ensure that the content of different model files is aligned with each other.

Each party must carry out consistency control on an on-going basis between its own model files and other parties' model files. These must be included in the project timetable.

A final interdisciplinary consistency control must be carried out on model files by completion of each phase or milestone.

If a collision occurs, the responsible parties must take action.

The working procedure for consistency control means that:

- Consistency control must advantageously be carried out on the principle of self-checking followed by interdisciplinary checks.
- Each party checks that its own model files are consistent with each other and between different disciplines.
- The parties jointly check that all model files across the project are consistent.
- The Banedanmark CAD coordinator makes consistency controls based on the delivered models.

The responsibility for finding clashes and inconsistency between the models and against existing conditions is always placed at the suppliers.

4.5 Visualization

Visualization is used in both technical and communicative contexts.

Visualizations can be prepared based on model files, or by producing special visualization models according to the purpose.

Valid data for construction must only be found in the models described in section 4.1. If new model files containing special or modified geometry must be created to perform the visualization (e.g. aesthetic modifications of 3D models), then it is not permitted to use these model files in other contexts.

4.6 Data extracts

Data extracts can be used for several purposes, like:

- Quantities
- Setting out data and machine control
- Schedule simulation

4.6.1 Quantities

Data extracts used for quantities must derive from the 2D or 3D models wherever possible. Where that is not possible, it must be clearly stated and documented where the quantities derive from, and which assumptions and estimations are used.

Major items/posts/tasks need to be divided into minor items. The source of the minor items must be clearly defined so the connection between the items and the design data is completely traceable within the whole project.

The documentation for quantities based on data extracts must include all relevant information regarding:

- Name
- Location coordinate x,y,z
- Length
- Width
- Height
- Amount
- Area, gross and net
- Circumference
- Radius/Diameter
- Volume

In the case of the tender project requiring Quantity Verification (mængdeverificering) as part of the winning contractor's performance following the award of the contract for execution, the winning contractor's documentation of quantities entails agreeing upon a reliable, final extent of the works tendered.
In the process of Quantity Verification, any deviations found between quantities surveyed by the winning contractor in the tender project and the quantities in the tendered Bill of Quantities (tilbudsliste) are to be documented in a Quantity Verification Document. The Quantity Verification Document must adhere to the structure of the Bill of Quantities, and the winning contractor must apply this same structure to document any deviations found in the verified quantities.
The Quantity Verification Document is the final assumption by the winning contractor, of any risk associated with the tendered quantities. When the contractor has verified the tendered quantities and provided a comprehensive Quantity Verification Document, any subsequent claim on the basis of quantities is not possible for the contractor. This will not include unforeseen works, scope changes or otherwise increased work. - However, if the contractor finds in their quantity verification process, that either the quantities are wrongfully surveyed in the tender (in case the scope of work is greater than the tendered quantities) or there are observable mistakes within the tender material, this will justify additional work and thus higher cost. In the case of higher costs, caused by detected errors within the tender material or by wrongfully surveyed quantities in the tender, the client is entitled to transfer these costs to the consultant along with a requirement to redesign the tender material. This redesign is to accommodate to any verified change in the scope of works, as specified in the contractor's Quantity Verification Document, with no charge to the client.

4.6.2 Setting out data

Setting out data must be generated either from discipline data, 3D models or 2D models and delivered either as geometry in a model file or as coordinate

lists or a combination of both. The formats and setup of the setting out data must be according to section 4.1.

4.6.2.1 Machine control

Machine control is generally used for earthworks. Where the technology is applicable, the necessary data must be generated from the models and discipline data.

4.6.3 Schedule simulation

A simulation of project site execution activities over time can be made, combining the data from models and time schedules. If data exchange between the parties is necessary to make the simulation, the extent of the data and formats must be agreed on between parties, these requirements will be stated in the ICT/IKT specification as well.

5 Documentation

5.1 Model file- and discipline data lists

Each supplier shall prepare a list of all delivered model files and discipline data. A template for this list is delivered by Banedanmark, and will be available to be downloaded from the CAD server.

The model file list must be uploaded to the CAD server and updated at the time of exchange with information about date of revision corresponding to each model's model block. The model list must indicate the overall delivery of models for each contract. The title/name of the models on the list and the filename must be the same.

The list must be updated for each upload. The changes must be highlighted in the list.

5.2 Drawing lists

Each supplier shall prepare a drawing list of all delivered digital plot files. A template delivered by Banedanmark will be available for download from the CAD server.

The list must be updated for each upload. The changes must be highlighted in the list. The title/drawing number of the drawings on the list, the filename and the drawing number in the drawing block must all be the same.

Depending on the amount of data, the drawing list can be divided in several files - one for each location. The division must be agreed with Banedanmark.

6 Exchange

The following files must be exchanged:

- Model files
- Drawing files
- Digital plots
- Discipline data files
- Assembly files

The formats for different file types are defined in section 4.1. and further explained in section 6.2.

6.1 Purposes

Exchanging files can serve multiple purposes:

- As basis for the recipient's model files
- As background for the recipient's drawing production
- To handover model file to other parties
- As background for interdisciplinary consistency control
- To inform and coordinate with external parties

In general, the sender is responsible for the content and structure of the exchanged files. In the event of amendments, the sender must submit new versions of models. The exchanged files must respect the requirements mentioned for each file type. The elements in the model files should be divided into levels in a manner that will allow the recipient to turn off – by the recipient - irrelevant elements.

6.1.1 Basis for the recipient's model files

The recipient uses the models as a reference to design their own models, which have dependencies to the received models.

The recipient may not modify the models received. The recipient is responsible for how other parties' models are used in their own production. Any amendments to the sender's models must be communicated to the sender, who subsequently makes the amendments.

6.1.2 Background for the recipient's drawing production

The recipient uses the models as reference files to create drawings.

The recipient may not modify the discipline models received. The recipient is responsible for generating drawings using the received models as references as well as for how external models are used in their own drawing production.

Any proposed amendments to the sender's models must be communicated to the sender, who subsequently makes the amendments.

6.1.3 Handing over model files to other parties

The models can be handed over to a recipient for further design/processing.

The sender is responsible for content and structure at the time of handover. The discipline code and any theme code in the filename must be changed by the recipient.

After handover, only the recipient's version of the model will be available. The sender's model will be archived and removed from the list of model files and can only be used to control the further design of the model. The recipient is now responsible for all modifications and updates.

6.1.4 Background for interdisciplinary consistency control

To control the consistency, the relevant parties and disciplines may exchange models. Upon finding conflicts, the parties must find a solution and agree who must modify their own model.

In the event of amendments to any model, the owner is responsible for submitting a new version.

The models delivered to Banedanmark are supposed to be the final version without inconsistency. Banedanmark's CAD coordinators make an overall control of the delivered material and prepare a report as response to the supplier.

6.1.5 Information and coordination with external parties

It can be necessary to exchange drawings and models with utilities owners and authorities, during design and construction phases. The process, interval and formats must be agreed on between the relevant parties.

The projects can be divided in different packages, designed or built by different parties. It will therefore be necessary to exchange data with other parties. In this case the extent of exchange of models and drawings must be agreed between the parties in an interface agreement.

6.2 Formats

Each discipline can work in their preferred application and format, but the different disciplines must be able to exchange files with Banedanmark and each other in formats specified by Banedanmark.

The responsibility for any conversion between valid model file formats or discipline data lies with the one making the file conversion. The use of any newer format must be agreed on with Banedanmark. When necessary the version of the software will be mentioned in the ICT/IKT Specification.

File type	Exchange format
Model files	DGN or DWG format
Drawing files	DGN or DWG format
Digital plots	PDF (as-built supplemented with TIFF format)
Discipline data files	Native format as well as LandXML format or LAS for point clouds
Assembly files	DGN, I.DGN or DWG format

Table 6.2-1 Exchange file formats

Different available formats for exchange will be used in the project for different purposes and/or programs, as shown in the table below.

Exchange file format	Description
LandXML*	For exchange of discipline data between incompatible applications (Open format). Also used for machine control, terrain models and alignments. The version must be agreed.
ALG	Bentley format used for alignment design, both roads and rails.
DTM	Bentley format used for design of terrain models.
SHP	ArcGIS format, used for geographic overview, e.g. for the 'Map of The New Line'.
DGN	MicroStation (Bentley).
DWG	AutoCAD (Autodesk).
I.DGN	I.dgn for exchange of intelligent models and geometry in 3D models from different applications. (Bentley)
IFC	Open format for 3D models
LAS	Open format for point clouds
POD	Bentley point cloud data format

Table 6.2-2 Exchange file formats

*Some information might be missing when converted to LandXML, such as layer/level names and components, therefore LandXML must be supplemented with CAD files, setting out data and geometry when necessary.

6.3 Procedures

6.3.1 Sender procedures

Prior to sending, the following must be done:

- The model file must be cleared of empty levels, unused complex geometric entities, etc.
- All levels are to be turned on
- Compliance with the drawing standard and level structure must be checked
- The geometry must be placed in the defined coordinate system
- The model- and drawing file list must be updated
- The model block, title block and revision log must be updated
- Checks must be conducted in accordance with section 8
- Regarding archive files: Any references in underlying levels/depths shall be merged to the top level

6.3.2 Recipient procedure

On reception, the following shall be carried out:

- Registration of received files
- Check of received files
- Information to the sender of any errors in the received files.

6.3.3 External exchange procedure

Files must be exchanged according to interface agreements between parties. The interface agreement must indicate the media for exchanging files, as well as exchange interval, data formats, coordinate systems and other relevant issues. The process for informing the relevant parties of data updates must be indicated in the interface agreement as well. The agreements must be available at the common exchange server.

6.3.4 Recommended test of the exchange procedure

If compatible software is used across the different parties, the models and discipline data can be exchanged directly, without necessary test of exchange. If the parties use different software, it is necessary to make a test of exchanging the discipline data and 3D model files. The test must clarify the most optimal conversion method to include as much information as possible.

Testing of the exchange procedure for discipline data files involves:

- Preparation of a discipline data file that complies with the agreed use of setup. The data file must as minimum include the elements, which will be necessary to exchange during the design.
  For alignment data the file must include horizontal and vertical geometry, super elevation (roads), cant and turnovers (rail).
  For surfaces the data file must include features and mesh components.
- Translation of the discipline data model to the agreed exchange format.

- The agreed checking procedures must be followed.
- The extraction of data in the agreed CAD file format must be sent with the test file.
- The discipline data transferred, must be checked for content as well as visually by displaying the imported data in a CAD file. Data extracts must be compared, and checks made that all types of data structure have been preserved.
- The functionality of the transferred entities must be preserved.
- The process must be repeated the other way, to ensure the conversion is possible both ways.
- A documentation describing the process and a check list must be prepared, so it can be used at the next conversion.

7 Quality assurance

In quality assurance (QA), the main emphasis is put on matters that are shown by experience to involve the greatest risk of failure.

The quality assurance of the technical content is closely linked with the consistency control described in section 4.4 The difference between consistency control and quality assurance is that quality assurance may not be performed by the person who created the building model or performed the data extracts.

Another important link within quality assurance of technical documentation is traceability between design data. The 3D CAD models, 2D extractions, discipline data, drawings, quantities and calculations must be coherent.

The supplier of data must document their processes to fulfil these requirements in their QA documentation, by describing:

- The CAD and 3D environment
- The approach to use 3D modelling during the design and construction phase including different extractions from the models e.g. drawings and quantities
- The applications used to generate the 3D models.
- Graphical control
- Consistency control
- Clash control
- Control of ICT/IKT-requirements due to models

The documentation must be available for Banedanmark on demand.

As a part of the approval process Banedanmark's CAD coordinators will make a control of the deliveries to ensure the consistency and traceability within the design data. The responsibility always rests with the suppliers.

The supplier is responsible for internal control of all CAD material, according to this CAD manual, before exchanging with other parties and deliveries to Banedanmark.

It is recommended that all parties make their own check lists, which must be used to ensure the quality of the deliveries.

8 Delivery

To manage the coordination of the disciplines, Banedanmark will establish milestones within each tender package, where all relevant disciplines deliver their 3D models. The models must be controlled for consistency prior to delivering to Banedanmark.

8.1 Partial deliveries

All models, drawings, digital plots and discipline data must be delivered by each shift of phase, and as specified in the ICT/IKT Specification.
Discipline data, 3D and 2D models, including drawing files, and digital plots must be available for exchange and delivery to Banedanmark on demand at any phase of the project, as specified in ICT/IKT Specification..
Where applicable, the models and discipline data must be delivered in IFC format too. The requirement will be defined further in the ICT/IKT Specification for the project.

8.1.1 Definition/Scope phase (Definitionsfase)

If models, drawings and data files are made for the Definition phase it must be delivered at time intervals, defined in the time schedule for the Consultancy Contract.

Banedanmark's CAD coordinator will comment on the delivered material and make a report, comparing the delivered material towards the requirements in the CAD manual and ICT/IKT Specification. Comments are to be worked out by the supplier during the phase and at latest before the change to next phase.

8.1.2 Program phase (Programfase)

Models, drawings and data files for the Program phase must be usable for different purposes such as estimating of the price, simulations, visualizations, environment analyses and defining the boundaries for expropriations, and must be delivered at time intervals, defined in the time schedule for the Consultancy Contract.

Banedanmarks CAD coordinator will comment on the delivered material and make a report, comparing the delivered material towards the requirements in the CAD manual and ICT/IKT Specification. Comments are to be worked out by the supplier during the phase and at latest before the change to next phase.

8.1.3 Design Phase (Projekteringsfase)

3D models and drawings must be delivered at time intervals, defined in the time schedule for the Consultancy Contract. Delivery of the models must be included in the project time schedule and coordinated with Banedanmark's

CAD coordinator. The extent of deliveries for each phase is indicated in ICT/IKT Specification for the project. The delivered materials at this phase must be detailed in a level that can be used for setting out and machine control.

Models and drawings and data files for the Design Phase must be delivered for third party validation. The technical evaluation of the delivered material will be done by the validator while the CAD coordinator controls the delivered data towards the specifications in the CAD manual and ICT/IKT Specification.

Banedanmark's CAD coordinator will comment on the delivered material and make a report. The supplier must update the material respecting the comments and deliver it as final design before the construction works begin in the field.

Besides the defined milestones it might be necessary to deliver 3D models ad-hoc. The supplier must be prepared to deliver the 3D models, digital drawings with short notice during the design phase.

8.1.4 Construction Phase (Udførelsesfase)

The contractor must carry out the necessary optimization of the designed models to be able to execute the constructions.
During the Construction Phase the contractor must be updated about possible changes to the project delivered by the consultant.
By changes during construction the designed models must be updated immediately.

The contractor must be prepared to deliver data at agreed milestones. The data, which registers the geometry of the construction will be used to follow the work in progress as well as preparing as-built models and drawings by comparing the QA measurements with detailed design. The QA shall be delivered according to the contract documents.

During the construction phase the contractor must deliver survey data for the performed works according to agreed intervals. The result must be delivered in 3D models including the as-built surface as well as the break lines and points used to generate the surface. The result will form the basis for the QA of the work performed.

8.2 As-built

8.2.1 Model files

The As-built models must reflect the survey data gathered in the Construction Phase.
In General contracts it is required that the consultant delivers as-built documentation in updated 3D model files. In Design-Build contracts responsibility for the delivery of the 3D model files lies at the contractor.

The as-built models must comply with the limit of tolerance described in the contract documents.

The 3D models created in the Design phase, must be compared with the measurement of the executed constructions. If the executed constructions meet the requirements for the tolerances in the relevant discipline, the Design models can be delivered as as-built documentation, without having to be updated.

If the executed constructions are not within the tolerances, the models and drawings must be updated according to the measurements of the executed constructions but keeping the properties and detailing level of the designed models.

The 3D models designed by the suppliers, may contain significantly more data than the models being exchanged and delivered in the exchange format. In this case, the suppliers must also deliver the models in the design software's original format.

See also section 4.1 for required exchange formats.

8.2.2 Drawings

As-Built documentation as digital plots and merged drawing files shall be delivered to Banedanmark in accordance with the provisions in "Krav til Teknisk dokumentation".
In general, it is required to deliver as-built documentation in accordance with “Krav til Teknisk dokumentation” and “Krav til Tekniske stamdata”.

Infrastruktur is the operation and maintenance organization in Banedanmark, to which the project will be handed over when completed.

Infrastruktur is divided into several sections, each have specific demands to the as-built delivery. The as-built documentation for each section must meet their requirements as well as the requirements in this CAD manual.
It might be necessary to change the file names, when delivering As-Built drawings. "Krav til Teknisk dokumentation" and its appendixes defines the file names.

8.2.3 Discipline data

All discipline data used to generate the models must be updated during the Construction Phase and delivered in original format as well as LandXML format as as-built documentation.

8.2.4 GIS data

Data must be delivered in DGN and ESRI SHP format with the content sorted according to the following main construction elements:

- UTM32 coordinate system
- Horizontal alignment
- Noise and vibration
- Environment and planning data
- Bridge and road facilities
- Expropriations
- Railway stations and station facilities

8.2.5 Delivery to external stakeholders

Having other stakeholders than Banedanmark, it might be necessary to deliver as-built CAD data to other authorities. In this case the deliveries have to be according the requirements from the respective authority.

9 References and glossary

9.1 Document references

1. Dansk Standard
   - DS/EN 15016-1:2004 Tekniske tegninger - Jernbaneudstyr - Del 1: Generelle principper.
   - DS/EN 15016-2:2004 Tekniske tegninger - Jernbaneudstyr - Del 2: Styklister.
   - DS/EN 15016-3:2004 Tekniske tegninger - Jernbaneudstyr - Del 3: Behandling af modifikationer af tekniske dokumenter.
   - DS/EN/ISO 128-20:2001 Teknisk tegning – almene tegneregler - Del 20: Grundlæggende regler for linjer.
   - DS/EN/ISO 128-21:2001 Teknisk tegning – almene tegneregler - Del 21: Tegning af linier ved hjælp af cad-systemer.
   - DS/ISO 128-22:2001 Teknisk tegning – almene tegneregler - Del 22: Grundlæggende principper og anvendelsesmuligheder for henvisningslinjer og referencelinjer.
   - DS/ISO 128-30:2002 Teknisk tegning – almene tegneregler - Del 30: Grundlæggende principper regler for afbildninger.
   - DS/ISO 128:1983 Teknisk tegning – almene tegneregler.

2. Banedanmark
   - Krav til Teknisk dokumentation
   - Krav til Teknisk data
   - Fritrumsprofiler
   - Banenorms and Tekniske Meddelelser

3. Det Digitale Anlæg (DDA)[2]
   - Level structure for infrastructure disciplines by Det Digitale Anlæg

4. Molio
   - C211, Layer structure 2015

5. DiKon
   - Anlægsdelsspecikifationer
   - Bygningsdelsspecifikationer

[2] "Det Digitale Anlæg" has changed name to "BIM Anlægsforum", but the layer/level structure has kept name and structure. See also chapter 9.2 Glossary.

9.2 Glossary

Word	Explanation
A-frames	Drawing frames are multiples of A4 size. Each fold is 210 mm long and 297 mm high.
ALG	Bentley format used for design of alignments.
Archive files	Archive files are copies of drawing files except that all references are linked to/merged with the drawing. Archive files can be used internally in the company to document the drawing's content at a given time or to exchange with other parties or delivering of As-built documentation.
Assembly files	Empty DGN or DWG file including attachments to relevant references within the same discipline.
Bentleyuser.dk	User group for Bentley products, such as MicroStation, which publishes standards for construction projects.
CAD Coordinator	The person responsible in each organisation for coordinating CAD tasks relating to a specific project.
Det Digitale Anlæg (DDA)	"Det Digitale Anlæg" (DDA) has been a corporation of the main actors within the infrastructure industry in Denmark to define common standards for the entire industry from 2012-2018. The organisation has changed name to "BIM Anlægsforum". One of the deliveries from DDA is the layer/level structure for CAD files. The layer/level structure keeps the same name and structure while updates will be taken place by BIM Anlægsforum. See http://biminfra.dk/bim-anlaegsforum/
DGNLIB	Empty MicroStation file containing level names, colours, line widths and line types for one or more disciplines.
Discipline data	Data files (not CAD files) used by applications. With file formats as ALG and DTM.
Digital Plots	Digital documentation of drawings in formats as PDF, TIFF, etc. Used for exchanging the drawings between the parties and as a basis for paper prints.
Drawing files	Drawing files are used to create and maintain drawing layouts.

Word	Explanation
DTM	Bentley format for Digital Terrain Models.
GIS	Geographic Information System to capture, store, manipulate, analyse, manage, and present all types of geographical data.
I.DGN	Format for i-models.
i-model	Intelligent file format to convert data and 3D models from different CAD applications to Bentley software.
Interdisciplinary files	Empty DGN file with references to 3D models from different disciplines, used for e.g. clash detection, simulation or visualization.
LandXML	Neutral file format for exchange of discipline data between CAD systems, which are not compatible with each other. Used for machine control, terrain models and alignments.
Layer/level	CAD files use layers/levels to identify different elements. Using the functionalities in the layers/levels within the CAD files makes it possible to use the same model in different drawings. The information indicated in the layers makes it possible for the different parties to understand the content of the exchanged CAD files.
Live nesting	The functionality in MicroStation, which allows usage of multiple level of referencing.
Model files	The geometrical information that is used to create, process and store the project is stored in model files. The model file is executed in 1:1 in relation to the actual measurement. Each discipline prepares its own model files and is responsible for updating them.
Molio	Member organisation that publishes standards primarily for the construction industry, previously known as bips
Notation files	Notation files are CAD files which contain standard elements as cells/blocks e.g. drawing frames, folder markers, title blocks, notes, etc.

Word	Explanation
Object number	All bridges and structures owned by Banedanmark are registered in a register and assigned an object number.
ProjectWise	The main CAD server for exchange of CAD data between the project's partners. Using ProjectWise, the server is common for all relevant parties, and is used for preparing, updating, exchange and delivery of CAD data.
Recipient	The party that receives exchanged CAD data.
Resource file	File that contains definitions of line types, text fonts, etc.
Revision	Revision is used to manage changes in drawings between to major stages of design.
Revision log	Table for managing and providing information about changes to the document. Must include the date of the change, the sections that are modified and a brief description of the change at each posting.
Seed file	An empty MicroStation file with the project's setup. The file will be copied when new files are created.
Sender	The party that sends exchanged CAD data.
Sketches	Sketches are temporary drawing files, which have a limited lifetime and should not be handed over to Banedanmark.
Supplier	The party in charge of preparing and providing CAD data.
Symbol fonts	Special text fonts that use the letters' positions and give them in the form of symbols. If you have not installed the font, you will get letters instead. Symbol fonts have been widely used by surveyors and in the production of basic maps.
Terrain model	A digital model of the terrain. It may be shown as triangles, components, mesh, contours or feature lines and points.
Version	Versions are used to mark the drawings with final status and to manage changes from a final stage to another.
Xref	AutoCAD's answer to Live nesting. See "Live nesting".