Data flow and object models in the railway design process

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Abstract

All through the railway planning and design process a huge amount of geographic related data is processed. The data assembly techniques varies depending on the need of accuracy for the different stages and from what sources the data can be retrieved. The main methods used for data collection are aerial, field and GPS-survey or by data transfer from existing databases or maps. To make certain that the data keeps the right quality through the whole process is it important to have the possibility to attach attribute data to the objects in use.

When data is retrieved from other sources, existing databases and maps, is it necessary that the data can be transferred in a proper way. This means that there has to be standards for data transfer of geographic information including attached attribute data. International standardisation work for geographic information is going in ISO/TC 211 Geographic information - Geomatics and in CEN/TC 287 Geographic information. Other IT - standards wich can be used in this area is ISO 10303 - called STEP. By participation in such standardisation work means that it will be possible to have global standards in the area of geographic information instead of local standards for every country. Every participant will also have the possibility to influence on the standard.

Modern GIS/CAD-systems including digital terrain models gives the possibility to handle 3D geographic information with attributes. With these kind of tools is it possible to build a 3D-model of the proposed railway formation including design parameters. This design model contains all information needed and can be used for presentation and visualisation, drawings production and all kind of coordinate based data can be extracted to be used on the building site.
1 Introduction

In the planning and design process of new infrastructure, especially concerning Roads and Railways, a huge amount of Geographic related data is processed. To take care of the data and to maintain its quality and durability during the whole process it is important to standardise the data transfer format on international as well as national level.

The new roles for many European Railway companies as administrators of the infrastructure and the information about it, which data can be used by Traffic organisations and others, makes it important to participate in standardising committees and works at all levels.

Advanced CAD-tools are used in the planning and design work. With these tools it is actually possible to build a model of the new construction. The model can be used for making extractions and presentations of drawings, to make presentation and visualisation. It can also be used on the building site to produce the data needed for setting out, control survey and quality checks. With the right tools the contractor can produce whatever types of drawings that is needed.

To use the tools and techniques of building an Object model and standardise the data interface to it with standard tools, e.g. STEP Data Application Interface (SDAI) using generic Application Protocol Interface (API), it is possible to use the same model in the integrated design work from different technical areas. This will allow improvement for the technical solutions and the total workflow.

This paper will introduce the works that is going on in standardisation of Geographic information and discuss different aspect around Object models for Railway design.

2 The Data flow in the Planning and Design Process

Planning and design of new Tracks
In the different stages of the planning and design process the need of accuracy of the data varies. In the early planning stages the data may come from existing maps in the scale 1:10000 - 1:50000 while in the last planning stage the scale needed might be 1:1000 - 1:5000 or from survey. All this depends on how sensitive the project is to the environment and to the people who are concerned of it. The more impact on the environment or how much it concerns the surrounding the more careful the planning work must be done.

In the detail design, however, the needs for accuracy is high. This means that maps can normally not be used for data collection. Instead the data comes from aerial and field survey. Some of the data outside the actual building site can be collected or transferred from existing digital maps or databases with high accuracy (e.g. houses, borders).
Using modern GIS/CAD-tools, the optimal way for design, is to build a 3D-model of the existing landscape using the collected geographical data. This can be a landscape model consisting of the ground surface, existing subgrades and the objects in the landscape.

**Network creation using GPS and network calculation**

Railway design with calculation of the track in the horizontal and vertical plane and in the end, the construction of the designed track, must be done with very high accuracy. This means that it is important that the fixed points from which the track is to be connected must be of a very high precision and accuracy. The way to determine these is to connect them to the national survey network using GPS. This means that the new points, close to the track, can get the same accuracy as the national network system (e.g. 10 mm accuracy).

**Data collection for Railway Design**

The data collection for railway design is made by different techniques. The main methods are field survey, GPS-survey, photogrammetric survey from aerial photos, digitising and scanning. For planning purposes, photogrammetric survey or scanning of existing maps, is used. Digitising existing maps are a very slow process compared to scanning and the following vectorising of the scanned data. Vectorised data with N-, E- and H-coordinates or data from aerial survey can be used for creating a digital terrain model over the wanted area.

**Aerial survey**

The flying altitude for detail design is normally 600 - 800 m. This produces aerial photos from which photogrammetric digitising are done. Using modern technics as digital photogrammetry the accuracy of a digitised point, in plane and height, is about 50-100 mm. From the photos is the ground surface surveyed by defining break lines, terrain lines and spot heights to be used for creating a 3D-model. In systems, using digital photogrammetry, are often software included for automatically producing 3D-points in a grid which, together with break- and terrain lines, can be used as input to a digital terrain model. From the same material are also all other data collected for SD-digital maps. This map information is stored together with the 3D-model.

**Field survey**

Objects, which needs to be defined with high accuracy, are surveyed by field survey. Such objects are, for railway design, for example the tracks, turnouts, platforms, catenary masts and other objects connected to the tracks. Areas and objects, that could not be surveyed from aerial photos, are also collected by field survey. All survey is done with reference to the network points which are placed along the track. The methods used for field survey are by using total stations with data collectors or GPS-receivers. New technology has proved that GPS-survey can be used for detail survey with enough accuracy.
Geotechnical survey

Normally is the geotechnical survey taking place at the same time as other data collection is going on. The survey points, in which different types of drilling methods are used, can be determined by traditional field survey or by using GPS. The results about the position of different stratas (sublayers) below ground surface and their characteristics are connected to the survey points. This information is used to create models for each sublayer. These models can then be connected to the 3D-model of the ground surface.

Feature coding of survey data

All objects, points or lines, must be coded with a feature code already at the survey stage. The code defines what kind of object it is (e.g. catenary mast, track, platform). Together with the feature code other attributes can be connected to the object. Such attributes might be quality, point label and material. The attribute quality can have values as accuracy, data collecting method, actuality and completeness. It is important that the object coding is consistent and follows the implemented standard for each country. Otherwise it is necessary with code conversion which can mean that the surveyed object loses the meant code quality. The same rules applies for the attributes. The codes and attributes are meant to follow the objects through the whole process from data collection, design, construction to the final administration phase.

Digital terrain model (DTM)

When all data collection work is done a DTM over the intended construction area is created. The 3D-model is constructed with data from all the different survey methods. The model, if it is optimal, should consist of all data for the ground surface, inclusive map information and the different substratas. In this way it is possible to handle it as one unit as a GIS/CAD-model. To make it possible to handle all this data together the DTM and its attributes have to be based on a database system from which it is possible to get access to the information needed. The commonly used DTM techniques for interpolation and presentation is the TIN-model (Triangular Irregular Network) but other techniques based on linear and 3D-functions to handle the levels of the different layers are in use. The DTM and GIS/CAD-model can be used for the design work of the new tracks.

Data transfer

The data collection and creation of the 3D-model inclusive the digital map is often done by consulting companies. This means that it is important that it is possible to transfer the data to the system of the customer. The data transfer can be at all levels. It can mean that the customer only want the surveyed data in form of coordinate files for the points and lines or that he want the complete data set with the GIS/CAD-model inclusive the substratas, map data, geotechnical survey data and all the attributes connected to the objects. To make this possible it is necessary to have defined standards for data transfer. These standards can be local for each country or based on international standards.
3 Geographic Information - International Standardisation Work

A lot of standardisation work are going on concerning geographic information. On international level the work is done by CEN on the European level and by ISO on the global level. In most countries are also local standards developed.

Global Standardisation work in ISO
Standardisation work on ISO-level concerning geographic information is done by ISO/TC 211 Geographic information - Geomatics. This work is divided into 5 different working groups (WG) and 20 projects of which the following can be mentioned:

- 1. Reference model
   The reference model describes the environment within the standardisation of geographic information takes place, the fundamental principles that will apply and the architectural framework for standardisation.

- 3. Conceptual schema language
   Adoption of a conceptual schema language for use in development of conceptual schemata in the field of geographic information.

- 4. Terminology
   A harmonised set of all specific terms that relates to the ISO/TC 211 family of standards.

- 7. Spatial subschemas
   Definition of conceptual schema defining the spatial characteristics of object types.

- 9. Rules for applications schema
   Definition of the rules for defining an application schema, including the principles for classification of geographic objects and their relationship to an application schema.

- 11. Geodetic reference systems
   Definition of the conceptual schema and guidelines for describing geodetic reference systems.

- 12. Indirect reference systems
   Definition of the conceptual schema and guidelines for describing indirect spatial (non-coordinate) reference systems.

- 13. Quality
   Definition of the schema for quality applicable to geographic data.

- 16. Positioning services
   Definition of a standard interface protocol for Global Positioning System (GPS).
European Standardisation work in CEN

Standardisation work on CEN level concerning geographic information is done by CEN/TC 287 Geographic information and the work is divided into 4 parts:

1. Fundamentals
   - Overview
   - Reference Model
   - Definitions
   - Dictionary for common terms

2. Data Description
   - Techniques
   - Rules for applications schemas
   - Geometry
   - Quality
   - Transfer

3. Referencing
   - Position
   - Time
   - Indirect positioning Systems

4. Processing
   - Query and update

Harmonising CEN and ISO standardisation work about geographic information is going on. This to make it possible to only have one international standard instead of different standards on the same topic.

ISO standards in use - STEP (ISO 10303)

STEP (Standard for the Exchange of Product Model Data) is so far the result of a roughly 10 years effort. The first 12 parts of this standard are available as international standards while an even greater number are in various stages of preparation. Some of the parts which can be used for geographic information are in particular:

- **ISO 10303-1**: Overview and Fundamental principles which establishes the framework for the remaining parts.
- **ISO 10303-11**: Information Modelling Language EXPRESS is a free form textual language with which it is possible to declare structures and assignment of individual names to their components.
- **ISO 10303-21**: Exchange File Format provides the means to encode data, described by an EXPRESS schema, as a sequence of ASCII characters. This sequence may be held in a file, passed across a network or between applications.
- **ISO 10303-22-25**: The STEP Data Access Interface (SDAI) is a generic API (Application Program Interface) to data described by a schema written in EXPRESS. It contains bindings to different programming languages as C, C++, FORTRAN.
- **ISO 10303-42**: Geometric and Topologic Representations.
4 Data Model for Infrastructure Design and Building

The design works are based on the GIS/CAD-model, which contains information of the existing landscape and objects in its database. The normal way to design the railway is to use cross sections of the existing ground and apply typical or standard sections together with the horizontal and vertical alignment on the cross sections. The cross sections of the existing ground are extracted from the DTM and hold information about the ground and the substratas. The typical sections are described by all parameters and their relations (e.g. variable slopes in different materials, dimensions of the overburden, ditches and drainages, distance between two or more tracks). To make it possible to make these descriptions the typical sections must be parametrical with relations between the different parameters and to the horizontal and vertical alignments. The resulting cross sections, which also includes the proposed railway formation, can be used for mass calculation. They are also converted into a 3D-model. To this model can other information, concerning objects related to the railway, be added. This information can be catenary masts, cables, piping and signals.

The 3D-model can be used for different types of presentation. The most used types of presentation are to extract information from the model and create drawings. Drawing in the plan view are normally used as maps. Other views can be presented as cross sections, longitudinal sections and detail drawings. The model is scale independent which means that the data is stored with the same precision as when it was surveyed and designed and it can be presented in whatever scale wanted. Visualization of the model of the new construction is very useful for the management and for other organizations who are concerned of the new construction.

As the model is scale independent and all information in it are based on coordinates it can be used on the building site. Normally the construction is based on a lot of drawings but with this technique, using a model, the drawings can be used for presentation of information. The actual construction with its coordinate based points and lines can be transferred to field computers from which the setting out work is made. All control survey of the construction can be fed directly into the model and thus it is possible to compare the built construction with the designed. It is also possible to update the model if there had to be changes in the construction by some reason. The resulting model, updated after the construction work, can in the end be sent back to the customer, who can use it for future administration.

5 Administration and Maintenance of Infrastructure

A big task for the railway management is to design and build a system for managing and maintenance of the fixed installations. This can be made in different ways. The common way is to use a standard GIS application and its database. Then it is important that the administrator has possibility to design the database and the connection to other inhouse databases. These databases can be centralised or
decentralised. But to make sure that the connection between the databases is handled in a proper way there has to be a central database manager (DBMS) that is taking care of this communication. Predefined application program interface (API) using standards for data management and definitions of data are then important. Unlimited number of users and applications may access data as long they are authorized to do so. The information definition model must then by definition be one and the same for all of them so the application knows what data it gets from the different databases.

Other ways to do this is to share data by exchange files. This is a more open case but still the data in the transfer file must be understood by the different applications. This means that the best solution is that data definition model even here must be the same. At least a the API:s ought to be from the same data definition model.

The GIS/CAD-model, created in the early stages for existing geographic information and then improved in the design and construction phase, is an important database for the future administration and maintenance of the fixed installations for railways. Thus it is possible to use the same model throughout the whole process with stages as planning, detail design, construction and maintenance.

6 Conclusions

Co-operation in the standardisation work on international level and with different users of geographic information makes it easier to define the structure of own databases. Using existing and common standards improves the quality of the databases. This will also reduce the amount of work when data are to be transferred between different systems. In the end this will reduce the costs of handling geographic information.

Working with modern 3D GIS/CAD-tools when building the data base for the fixed installations makes it possible to use the same data in the different stages as planning, design, building and maintenance.
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