CO-321

TOPOGRAPHIC LINE MAPS FOR MILITARY PURPOSES

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BACKGROUND AND OBJECTIVES

Standardized cartography and international data standards like the European INSPIRE data model, allows the shared use of data for civil and military purposes. Centralizing topographic data in an international accepted data model standard makes redundant data repositories no longer necessary.

The challenges today are:

- the secure data handling in online workspaces,
- cloud computing with sensitive and secure data,
- the rapid collection of up to date information and data from reliable sources that meets the demands on accuracy of the position and the level of detail,
- the access of the required information from the huge amount of available data through geospatial data mining,
- the metadata management,
- as fast as possible updating of maps for various output formats,
- the quality assurance of the data and the cartography,
- the security of the data and the restricted access through access authorization

The production of a 1:50,000 Topographic Line Map (TLM50) should be given as an example.

The TLM50 is a representation of terrain detail showing features such as single houses, urban areas, hydrology, transportation networks, infrastructure, landmarks, cultural features, topography, vegetation, contours, spot elevations and political boundaries and therefore portrays the greater detail of topographic and cultural information. The correct orientation and true location of the features are one characteristic of the map. The TLM50 provides basic terrain analysis information in sufficient detail to support intelligence preparation of the military operation and to navigate in various terrain environments including jungle, mountain, arctic or desert.

During the preparation of military operations the needed geo-data is often not available or too old and there is no time or possibility for surveying.

The collection of reliable existing data and information is a central and important precondition.

Based on those information and data, the map production should be automated and referred to the military standards of a 1:50 000 map specification.

APPROACH AND METHODS

Existing data sources:

For standardized and rapid mapping the sources for cartographic processing have to be prepared for an automated extraction of the needed information.

Those processes can be automatic interpretation of satellite images, extracting contour lines from DEM, database analyses and WEB Geo-data services.

For the TLM50 maps, topographic data for some areas is available in VMAP2/MGCP Format as Feature code separated Shapefiles. The VectorMAP Level 2 data or Multinational Geospatial Co-Production Program (MGCP) data are vector databases derived from satellite image interpretation and other sources. Those data have been verified in a high level quality control process.

The contour lines can be derived automatically by Spatial Analyst with a predefined equidistance of e.g. 10 m.

Depending on the available time period and other reasons, it is in some cases not possible to purchase new high resolution satellite imagery and a DEM. In this case the digital elevation model has to be generated from different available sources with different accuracies e.g. SRTM C-Band (NGA), SPOT or Paper Maps. Because of the various sources with different resolutions some manual work will be necessary to correct misinterpretations.

Geo-names:

The official collection of foreign Geo-names by the U.S. Board on Geographic Names and the NGA contains approximately 4 Mio. objects with 5.4 Mio. geo-names in a worldwide coverage with exception

of Antarctic and USA. The data is available online in a .txt data format without legal usage limitation. Updates are online on a two weeks basis with 20 000 updates each month. The sources are national Mapping-Authorities of the nations, official governmental documents, existing JOG 1:250k, and many more. The coordinates are giving only approximate position.

To approach best possible results all available sources have to be utilized and put into a hierarchical order according to the degree of reliance.

Sources for cartographic information can be

- Satellite imagery
- Aerial photography
- Digital elevation models like DTED2
- Governmental Topographic Data and Maps
- National or international data sources (spatial databases, CAD drawings, paper maps)
- VMAP1 (vector JOG/250k) and VMAP2/MGCP (vector TLM/50k/100k)
- Gazetteers
- Open Street Map (OSM)
- Google Earth and Google Maps

In addition to the data sources, the technical specifications, the data model and metadata build the basis for the cartographic processing of the maps.

For the military TLM production the unclassified specifications are the

Military Standards of

- Levels of Protection,
- Product Generation Rules,
- Symbolisation,
- Glossary of Feature Attribute Definitions,
- Accuracy,
- Reproduction and Printing,
- Bar Coding
- DMA Technical Manual (DMA TM) “Datum’s, Ellipsoids, Grids and Grid Reference Systems.” and “The Universal Grids; UPS and UTM Grids.’”
- Geodetic Reports of the NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY (NGA)
- Standard Printing Color (SPC) Catalog
- Specification of TLM50

Those standards and specification assure uniformity of treatment among all mapping and charting elements engaged in a coordinated production and maintenance program for the TLM product.

The Feature Attribute Coding Catalog (FACC) is the approved coding standard for the exchange of digital geographic data.

Field structure exemplarily:

For example: FACC Code AL - Culture-Miscellaneous Features

AL015 Building

A relatively permanent structure roofed and usually walled and designed for some particular use.

Attributes

ACC ACCURACY CATEGORY
A00 ANGLE OF ORIENTATION
ARA AREA COVERAGE ATTRIBUTE
BFC BUILDING FUNCTION CATEGORY
COE CERTAINTY OF EXISTENCE
EXS EXISTENCE CATEGDRY
BGT HEIGHT ABOVE SURFACE LEVEL
SWT HOUSE OF WORSHIP TYPE
LEN LENGTH /DIAMETER
LMC LANDMARK CATEGORY
NAM NAME CATEGORY

TUC TRANSPORTATION USE CATEGORY
ZVL Z VALUE
Example Values for the fields BFC and EXS:
BFC Building Function Category
0 Unknown
6 Hospital
7 House of Worship
8 Military Administration/Operations Building
15 School
16 House
30 Hangar
36 Barracks/Dormitory
37 Fire Station
999 Other
EXS Existence Category
0 Unknown
5 Under Construction
6 Abandoned/Disused
7 Destroyed
28 Operational
3 examples of Product rules for PAL015 Buildings:
Point Features:
D-1652 If features coalesce at map scale when shown in their true positions, they shall be displaced 0.2 mm from one another.
O-3008 If coalescing features being thinned are a mix of heights (HGT), with some < 46 m and some > 46 m, then only the obstruction symbol shall be shown.
R-2495 Symbolize apron/hardstands (1Q060), and buildings (1L015) inside areal aircraft facilities (1U030, AFT001 (Airport) or 003 (Seaplane Base))
Parameters:
Following parameters for the TLM50 must be maintained
Accuracy for points such as cross roads, point features, diagnostic and control points, etc.:
Absolute horizontal accuracy is 1.0 mm (50 meters) circular error (CE) at the 90% confidence level. Absolute vertical accuracy is one contour interval linear error (LE) at 90% confidence level.
The projection for 1:50,000 Scale Topographic Maps product is the Universal Transverse Mercator (UTM) with WGS 84 datum for 80 degrees south latitude to 84 degrees north latitude. Above or below these latitudes the projection is the Polar Stereographic.
The Vertical Datum is mean sea level (MSL).
Map Sheets are so positioned that they coincide with the grid, ellipsoid, and datum junctions wherever possible. The sizes of Map Sheet may vary within a map series.
Standard TLM50 map sheet sizes and the latitudes at which they occur:
Latitude Map Sheet sizes N-S E-W
0° to 36° 15’ x 15’
36° to 44° 15’ x 18’
44° to 50° 15’ x 20’
50° to 61° 15’ x 22’30”
61° to 67° 15’ x 30’
67° to 72° 15’ x 36’
72° and above specified in instructions for the assignment
Languages:
When required by international map standardization agreements or bilateral cooperative mapping arrangements, certain margin items are translated. The language or the maximum of two languages to be shown, in addition to English, are the surrounding map elements like the Legend, Unit of Measure,

Contour Interval Note, Grid and Projection Information, Instructions on Grid Referencing, Glossary, Applicable Notes, Bar Code Text, Copyright Note, Users Notes, Security Classification and others.

Software:

The software for the cartographic production consists of different GIS software, converter QA extensions and raster editing programs.

Following software applications have been used:

- ESRI ArcGIS 9.3
- ESRI PLTS 9.3 (Production Line Tool Set) Defence Solution
- Global Mapper V10
- TerraGo Map2PDF
- Enfocus PitStop
- OneVision Securic
- Adobe Creative Suite 4

Program: Production Line Tool Set (PLTS)

The symbolisation and the data model have to be up to standard military specifications. Containing the complete data model of the TLM including predefined layout, the PLTS (Production Line Tool Set) Defence Solution based on ArcGIS from ESRI is applied.

This tool is composed of a series of extensions for

- data migration, editing and maintenance (Foundation Tools)
- quality control (GIS Data ReViewer)
- map production (Map Production System (MPS) and MPS Atlas).
- workflow management (Job Tracking for ArcGIS (JTX))

PLTS Defense Solution

The PLTS Defense Solution is working with several data specifications of the following map series:

- Image City Map (ICM) and Digital Image City Map (DICM)
- Stereo Airfield Collection (SAC)
- Urban Vector Map (UVMap),
- Theatre Geospatial Database (TGD) – Global-, Strategic-, Tactical-, Urban Operations
- Vector Map Level 0 (VMap0) 1:1,000,000 Operational Navigation Chart
- Vector Map Level 1 (VMap1) 1:250,000 Joint Operation Graphics (JOG)
- Vector Map Level 2 (VMap2) 1:50,000 and 1:100,000 Topographic Line Maps (TLM)

Foundation Tools

Data models

The data model is essential to the product specification because it provides a purpose for the layer and feature class structure. This information is contained in the Geo-database.

Knowledge base

The central knowledge base serves as a repository for all information related to database models and their associated product specifications. This includes the hard-copy and digital products associated with the data models and the content and visual requirements for them. With PLTS the Geo-database is extended to include additional rules for on-the-fly validation, complex rendering, and feature metadata management. These tables also interact with various tools throughout the PLTS system. PLTS utilizes the knowledge base to control valid feature attribution and feature symbology. The knowledge base must be loaded into the Geo-database where the data is stored to be accessible to the PLTS system.

There is a different knowledge base according to the different map series.

Domain tables are defined as part of the Geo-database and are used to control input to a field. The PLTS Geo-database has been built with coded value domain tables defined.

Map Production System (MPS)

The MPS is the component of PLTS that allows the creation of cartographic products that consistently meet specifications. Individual map sheets associated with an Area of Interest or an entire map series can be created and designed.

MPS provides a full set of cartographic editing and generation functions that include:

- Tools to choose map sheet geometry
- Tools to automate map production

- Surround elements customized to the map series
- Relational placement of map elements
- Cartographic editing tools
- Ability to receive and deliver custom map series information

Project and Map Sheet Catalog (PMC)

The PMC is a Geo-database and an integral part of the MPS.

The PMC contains many important elements of the map product, including:

- All of the available Areas of Interest (AOI) for each map series
- All of the properties for the MPS Surround Elements
- All of the Placement Rule information
- Feature datasets and feature classes for the Boundary Guide, Adjoining Sheet Guide, and Elevation Guide
- Index of map sheets used in the generation of the Adjoining Sheet Guide

TLM50-Production procedures

1. Preparing the source data:

Applications: PLTS, ArcMap, ArcCatalog

Loading MGCP/FACC-Data into PLTS Geo-database and Symbolizing according to the Specification. The source data has to be converted from Shape format into PLTS Workspace (Geodatabase) and afterwards analysed as a first step of quality assurance and data control with PLTS Data Reviewer. During the data integration the data model and the predefined symbolisation results in a correct map layout. Any discrepancies are immediately visualized and localized.

Definition of the equidistance and classification of contour lines:

Depending on the terrain the equidistance of the contour lines has to be set-up to 10 m, 20 m or 40 m. The contour lines have to be classified according to count lines, intermediates and help lines.

Because of the different symbolization of contour lines in areas of sand, glacier and ice, the contour lines needed clipping and change of attribution according to areas of sand, glacier and ice.

The Projection and Rotation angle of the data frame has to be set-up to the map sheet parameters.

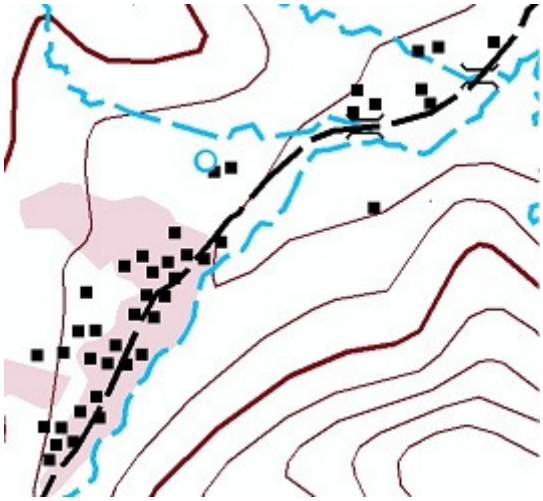
2. Coordinate GRID and automatic Rotation of Point objects

Applications: PLTS

Changing of attributes of Culverts (PAQ065: width and length) according to street class was proceeded by SQL queries and automatic object rotation. The PLTS Bridge Renderer assists with the adjustment of the length of bridges (LAQ040) according to the situation of a river.

The adjustment of single houses (PAL015) along street axes by automatic rotation:

In certain cases it is possible to rotate single objects automatically in ArcGIS. For example at single house presentation (up to 10 000 per map or more) all houses with a defined distance to the roads will be rotated with orientation to the roads.



Picture 1: Original data recording and contour lines

Picture 2: Situation after automatic rotation

Generation of the Coordinate GRID with PLTS/Grid Manager:

The Generation of the UTM Grid, including layout, set-up of the map specific projection parameter and map rotation as well as labelling, is effected full automated through the PLTS Grid Manager.

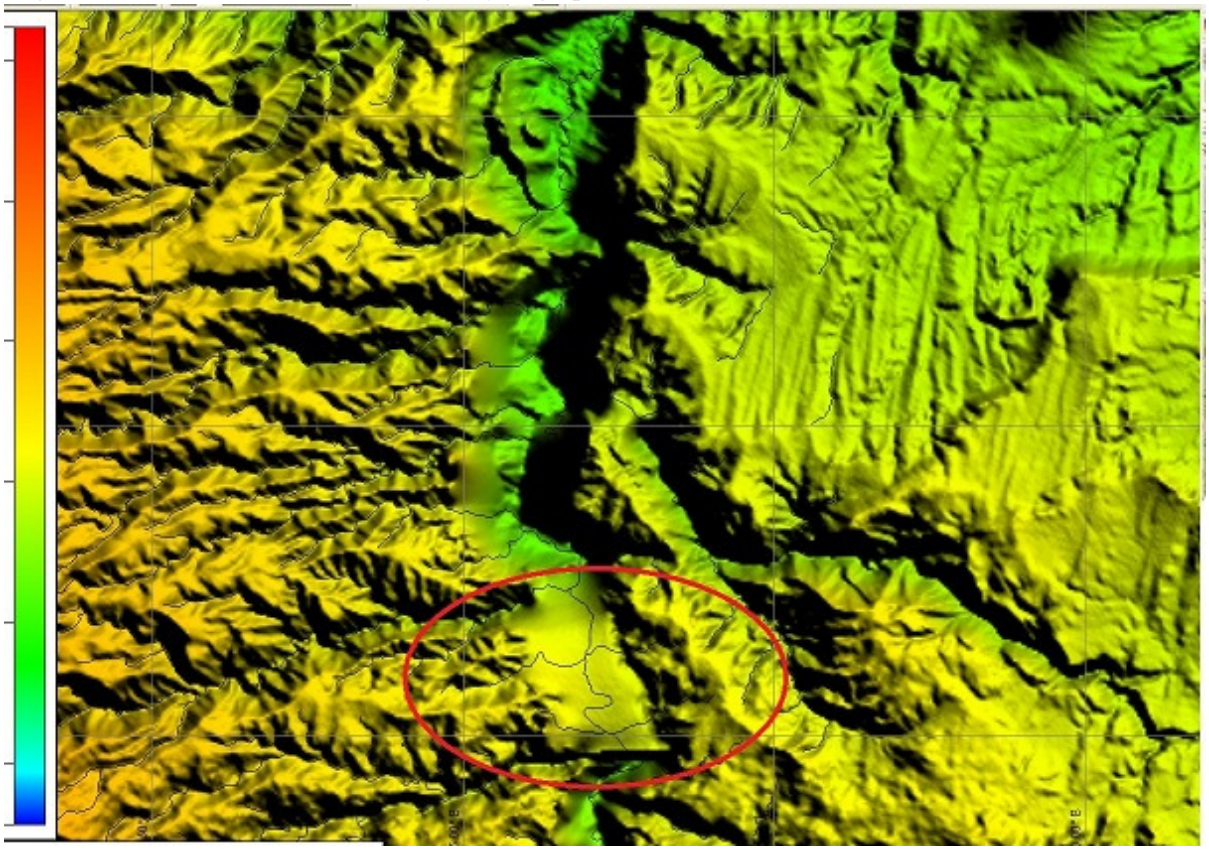
The Grid Manager contains predefined grids, graticules and borders for a variety of map products including the TLM50 grid specifications. During the grid creation all the definitions and rules are loaded from a XML file. New feature datasets, feature classes and features modeled as cartographic grid components in a specified file, SDE or personal Geo-database are generated. The grid can be modified and stored a new predefined grid model in a new XML file.

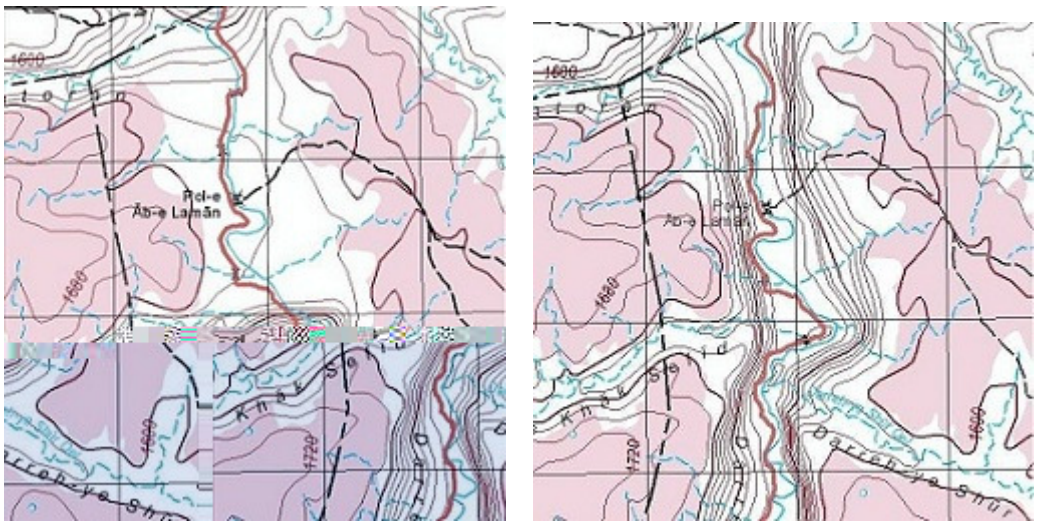
3. Cartographic editing

Applications: ArcMap

Cartographic adjustments like generalising, displacements, adjustment of the contour lines to the topographic situation (e.g. hydrographical situation) or object rotations is semi-automated. The compliance of minimum distances according to the specification of the TLM is subject to an automated control process.

Adjustment of contour lines according to hydrographic situation





Picture 3: In the lower middle area of the DTED2 picture there is an error recognizable, which leads during the automatic derivation of the contour lines to misinterpretation.

Instead of continuing the valley there is a saddle displayed (left picture)

In the right picture there are the updated contour lines displaying the correct situation as a valley.

Further tasks:

- Automatic generation of contour line numbers and adjustment
- Revision of the map frame and matching the situation to the neighbored map sheet
- Individual rotation of single objects like PBH170 (Springs) or PBH145 (River Vanishing Points)
- Adjustment of road changeover according to overlapping and gaps at built up areas and road crossings
- Revision of water bodies in glacier and ice areas
- Color adjustment to red light readability

4. Names and Glossary

Applications: ArcMap, ArcCatalog and GlobalMapper

The names in a TLM50 for military purposes are the most sensitive production part. The most reliable information has to be extracted from the different sources.

The TLM contains descriptive labels to the fetures like "Wall", "Tower" or "Various Ditches". The symbols in the TLM are often similar according to different objects. Therefore an annotation specifies the feature in the map like "abandoned", "operational" or "approximately" if a boundary is not definit.

These are the production steps for the naming of the TLM50:

- Preparation of labels (Annotation FeatureClass)
- Labeling of objects based on MGCP/FACC-Attributes
- Labeling based on Gazetteer-Points
- Alignment of hydrographic names by other sources
- Derivation of the Glossary

Picture 4: Original data recording and contour lines

Picture 5: Processed situation

After the completion of the cartographic names based on the Gazetteer and other sources according to cartographic and geographic aspects, elevation points have to be derivate from the digital elevation model.

5. Automatic generation of surroundings

Applications: PLTS

The Map Production System (MPS) generates the entire required surround elements needed to meet the TLM50 Specifications. Surrounding features are processed full automated. At the margin of a TLM map sheet following elements are placed in a specific order according to the implemented Placement Rules. All surround elements will be positioned in the proper location on the page layout.

The MPS software generates two main types of surround elements on a map sheet.

Grouped graphic elements:

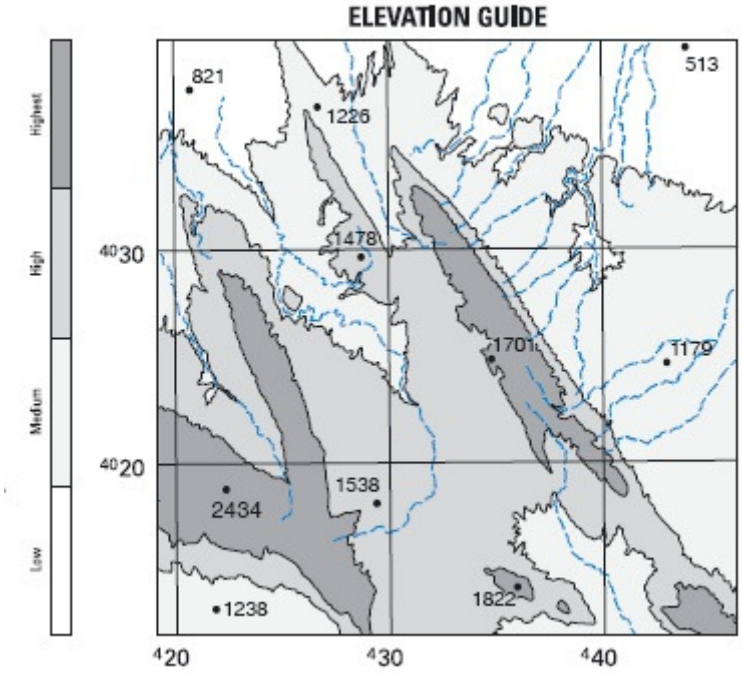
UTM- Meter Reference, Map specifications, North arrow, Scale bar, Legend, Glossary, Barcode, Slope Guide, Conversion Graph, User notes, Copyright, Limited distribution note

Grouped feature elements with a data frame in the Geo-database:

Elevation Guide, Boundary Guide, Adjoining Sheet Guide

Once the map sheet is saved as a MXD, elements (text, line and poly symbols) on the map sheet can be easily ungrouped for editing.

PLTS software generates automatically the elevation layers out of the DEM.



Picture 6: Elevation Guide

6. Quality Control I and II

Applications: ArcMap, Enfocus PitStop

The QA process is carried out in several steps and completed by a certified colour inspection trough the Adobe Acrobat extension Enfocus PitStop. The colours are adjusted to red light readability.

- Quality Control I and separate proofreading of the contour lines
- Quality Control II

- Inspection sheet I and II

7. Technical Quality Control

Applications: ArcMap, PLTS Data Reviewer

The PLTS Defense review tools add a variety of specialized validation tools that allows to check the relationships between different feature classes and geometry types as well as proper feature attribution.

Data quality is ensured through several methods. In-process automated quality control is built into the database model and controls the available attribute values for many fields. PLTS extends the in-process automated quality control and includes tools that can be used to discover and log data errors for review and correction cycles. Additionally, topology rules can be applied to ensure the topologic relationship between features. Both automated and manual quality controls are employed to ensure high-quality data.

8. Completion of final data

Applications: ArcMap, Enfocus PitStop, OneVision Sicuriq, TerraGo Map2PDF

- Output of printable PDF files
- High resolution TIFF rasterized with Sicuriq
- GeoPDF export with TerraGo Map2PDF
- PDF Certificate through Enfocus PitStop Inspector in ADOBE Acrobat

RESULTS

The output formats are high quality PDF for paper prints, GeoPDF, Raster- and GIS data.

The MXD layout documents and Geo-database are prepared for contemporary processing updated maps.

The military layers are separated from the topographic features and can be turned off for civil use of the maps. The GeoPDF allows the direct use of maps on laptops in military vehicles.

CONCLUSION AND FUTURE PLANS

For military mapping the claim of highest accuracy of each single object within the map is essential. The readability of the maps under adverse conditions has to be guaranteed.

The GIS environment offers the opportunity to update the map with information coming in real time from the field. Data collection by mobile devices can be transmitted directly into the map on a central server and be available for all users with access to the data.

By an updated data model the implementation of restrictions of the roads can be used for a simple navigation with the data on hand held's.

The map could be prepared for online usage in WMS and the connectivity to external sources like WIKIPEDIA could offer an added value by having additional information available to single map objects.