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Sustainable SDI for EU noise mapping in NRW – best practice for INSPIRE *

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Abstract

The Environmental Noise Directive of the European Union 2002/49/EG (END) obligates the EU member states to determine every 5 years the noise emission of major roads and railways, major airports, industrial activity sites and urban agglomerations and to document the results in noise maps. It poses high requirements, as a great number of statewide and ubiquitous geodata and thematic data in the third dimension is necessary (terrain, buildings, roads, railways). To provide these considerable amount of statewide 3D geodata, the state of North Rhine-Westphalia (NRW) follows a modern implementation concept, the sustainable use and enlargement of the Spatial Data Infrastructure GDI NRW. NRW provides for the first time statewide 3D geodata as features in CityGML via OGC Web Feature Services (3D building models in LOD1, ATKIS 3D road and railway data) and the Digital Terrain Model 10m grid via an OGC Web Coverage Service. CityGML is used as sole common exchange format between web services and noise calculation software to solve syntactic and semantic interoperability problems. A CityGML data base is realised, which contains approx. 10 million buildings.

This article demonstrates the architecture of geodata provision, the 3D modelling in CityGML, the geodata refinement and interoperability tasks as well as the noise calculation results.

Keywords: noise mapping, spatial data infrastructure, INSPIRE, web services, CityGML, GDI NRW

1. INTRODUCTION

The Environmental Noise Directive of the European Union 2002/49/EG (END) poses high requirements to the EU member states. These requirements evoke great problems in realisation and implementation, especially in North Rhine-Westphalia (NRW), the federal state of Germany that is highly affected by the END (Czerwinski et al. 2006a, 2006b). To overcome the challenge, the state of NRW decided to follow a visionary and modern implementation method for noise mapping: sustainable use and enlargement of the Spatial Data Infrastructure GDI NRW for EU noise mapping. Web services standardised by the Open Geospatial Consortium (OGC) are implemented for huge statewide environmental geodata, using the single standardised exchange format CityGML (City Geography Markup Language, Gröger et al. 2007). The architecture allows a quite automatical procedure of web service data access, noise immission calculation and portal provision of results. As these goals are in the focus of European Union as well, NRW provides already at present an implementation example for the new EU Directive on INSPIRE (Infrastructure on spatial information in Europe). (European Union 2002, 2007)

The END obligates the EU member states to determine every 5 years the noise immission on buildings and to document the results in noise maps. Environmental noise sources are major roads and railways, major airports, industrial activity sites and urban agglomerations. The noise maps serve as information for the European Union and the noise affected citizens. These noise maps are calculated on the basis of acoustical models and noise propagation calculations, not on basis of measurements (Czerwinski et al. 2007). As the noise immission is calculated at a height of 4m on buildings and concerns vertical reflecting surfaces, a great number of geodata and thematic data in the third dimension is necessary for each EU member state. Because of the spatial expansion of the noise calculation, the provision of statewide and ubiquitous 3D geodata on buildings, roads, railways and terrain for a multitude of users is necessary, in part with very high requirement on resolution. In Germany the municipalities are primarily responsible for the environmental noise mapping (except for railways in federal ownership). (Federal Government of Germany 2005)

These demands pose a challenge for all responsible actors, as time- and cost-consuming data flows especially of (3D) geodata, excessive personal demand especially in municipalities < 100.000 habitants as well as a missing use of homogeneous basis data can be observed. This is even more challenging, as the time for realisation is limited primarily to the 30-6-2007, so less than one year to implement.

In North Rhine-Westphalia, special conditions have to be considered: high population and transportation route density and therefore the highest amount of noise calculation areas and objects in Germany. NRW is mostly affected by the END because of its high amount of agglomerations (12 > 250.000 habitants, ~60 > 100.000 habitants), responsible municipalities (350 of 396) and number of exposed people (Czerwinski et al. 2006b, Stöcker-Meier et al. 2007). To support the smaller towns the State Agency for Nature, Environment and Consumer Protection of NRW prepares the noise maps outside the agglomerations.

Figure 1: Project partner of the realisation of EU environmental noise mapping in NRW, first iteration in 2007
(Graphic: Institute of Geodesy and Geoinformation University of Bonn)

The aim is to provide a long-term, efficient and variable access to the required 3D geodata for the 5 years iterations and the different noise calculation authorities. The web service access to distributed data avoids a multiple data storage in noise software tools and allows a use in further applications. Furthermore, a syntactic and semantic interoperability of the different required 3D geodata has to be established.

The realisation of the EU environmental noise mapping in NRW based on the Spatial Data Infrastructure is sustainable in two ways. On the one hand, it allows financial savings of about 77% for 3D geodata generation and provision compared to proprietary architectures and 15% for 3D geodata integration and refining (Plümer et al. 2006, Czerwinski et al. 2006a). The 77% are caused by a centralised 3D geodata generation (e.g. 3D block models in CityGML from the State Mapping Agency), a use of web services for data access instead of manual data copies, the syntactic interoperability via CityGML instead of data conversion into different formats, and the sustainable use of the architecture for all iterations. The 15% due to a 3D geodata refinement based on web service access, a 3D geodata integration via a transactional Web Feature Service and only few licence fees. On the other hand, the architecture can be extended and modified flexibly in the future according to the current requirements.

2. STATEWIDE 3D GEODATA PROVISION

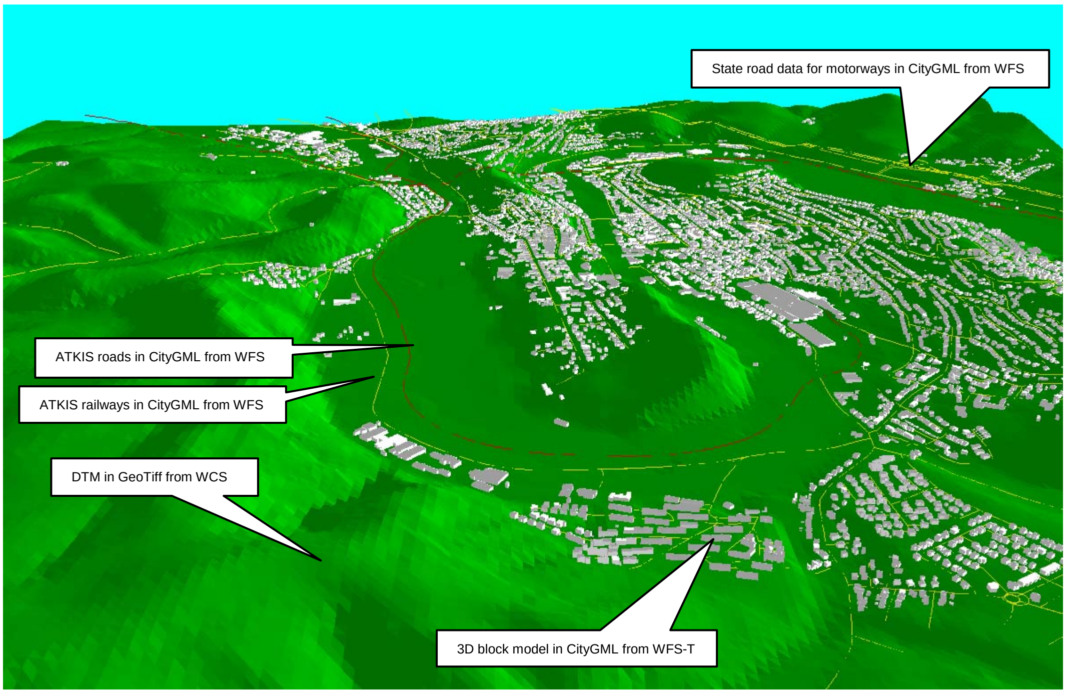
The main 3D geodata, which have to be integrated for noise mapping, are: Digital Terrain Model 10m grid, 3D block model Level of Detail LOD1, ATKIS road and railway data, federal state road traffic data, address data (Figure 2). These geodata are provided in NRW at different sources and formats, which complicates their provision and integration.

Thanks to a successful cooperation with federal state geodata authorities (Surveying and Mapping Agency NRW, State Road Enterprise NRW) a rapid 3D geodata provision was realised in only 6 months for the whole area of NRW and the affected regions:

- Digital Terrain Model (DTM) 10m grid, scale 1:5000 (source: Surveying and Mapping Agency NRW): statewide provision, data collection via laser scan, stereo-photogrammetry and digitalisation
- 3D block model Level of Detail 1 in CityGML format (source: Surveying and Mapping Agency NRW): statewide provision (approx. 10 million buildings), generation was realised by the use of FME (Feature Manipulation Engine) and by linking ALK cadastral building outlines, DTM, cadastral thematic information (addresses, building type, function, building id, external reference to information system) and building height information (laser scan, number of storeys or standard estimations). The integration of the 3D block models in the DTM was realised by appropriate CityGML modelling (lowest point of ALK building outline is taken as measure to generate the building bottom side, see Figure and chapter 4). The integration of cadastral information is essential to

assure an appropriate data continuation (Figure 3). In Germany cadastral information is provided by the systems ATKIS (Authoritative Topographic and Cartographic Information System) and ALK/ALKIS (Automated Real Estate Information System) and is composed of vector data (Busch et al. 2002).

Figure 2: 3D Geodata in CityGML for the calculation of the noise map in Figure 11: DTM in GeoTiff, 3D block model in CityGML, ATKIS road and railway data in CityGML, state road data for higher-level roads in CityGML



Source: Surveying and Mapping Agency NRW, State Road Enterprise NRW, Stapelfeldt GmbH, Institute of Geodesy and Geoinformation University of Bonn

- ATKIS road and railway data (source: Surveying and Mapping Agency NRW): statewide provision, dense road network including motorways, federal state roads, district roads and in-town streets, but few thematic attributes/information (e.g. road name, function, distance of carriageway), 3D modelling and provision in CityGML (see chapter 4)
- state road traffic data (source: State Road Enterprise NRW):
    - o 3D road segments affected by the END (approx. 3800 km in the first iteration in 2007): including only motorways and federal state roads, but a great number of thematic attributes required by the END (e.g. traffic flow, heavy vehicle percentage, speed limit, type of road surface, road gradient, width of a road), 3D data collection by drive GPS measurement and video

analysis, provision of thematic attributes by measurement or standard estimations
    - according 3D noise barrier segments: 3D data collection by drive GPS measurement and video analysis, provision of thematic attributes required by the END (e.g. reflection, barrier type) by measurement or standard estimations
- information on inhabitants (source: municipalities): collected from all municipalities in a given format or standard estimations if not available (no provision to the public – only aggregated information on noise affected inhabitants).

Figure 3: Generation of 3D block models LOD1 in CityGML integrating cadastral information


```
<cityObjectMember>
<Building gml:id="UUID_cf656c96-56b5-410d-8b2e-a49c31308aef">
<gml:name>Wohnhaus_allgemein</gml:name>
…
<externalReference>
<informationSystem>
file:///L:/FB43_GeoDatZ/2006172_Laermkartierung MUNLV/Katasterbehoerde/LEV/05316000.zip
</informationSystem>
<externalObject>
<name>HA05316000023300038___a001</name>
</externalObject>
</externalReference>
<stringAttribute name="HH-Entstehung">
<value>LASER</value>
</stringAttribute>
<function>1301</function>
…
<Address>
<xalAddress>
<xAL:AddressDetails>
<xAL:Country>
<xAL:CountryName>Germany</xAL:CountryName>
<xAL:Locality Type="Town">
<xAL:LocalityName>Leverkusen</xAL:LocalityName>
<xAL:Thoroughfare Type="Street">
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<xAL:ThoroughfareName>MueHLENWEG</xAL:ThoroughfareName>
</xAL:Thoroughfare>
<xAL:PostalCode>
<xAL:PostalCodeNumber>51371</xAL:PostalCodeNumber>
</xAL:PostalCode>
</xAL:Locality>
</xAL:Country>
</xAL:AddressDetails>
</xalAddress>
</Address>
…
</Building>
</cityObjectMember>
```
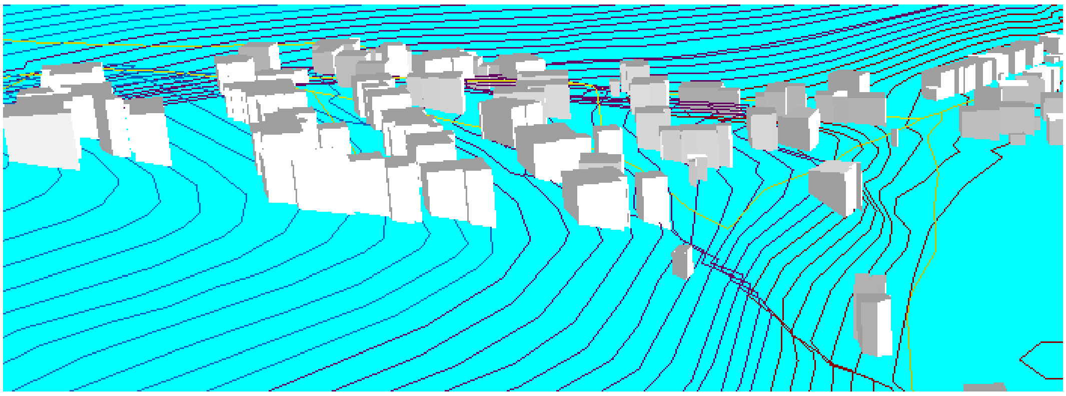


Source: Surveying and Mapping Agency NRW, Institute of Geodesy and Geoinformation University of Bonn

Figure 4: shows the integration of 3D block models LOD1 in the DTM by appropriate CityGML modelling (lowest point of ALK building outline is taken as measure to generate the building bottom side).



Source: Surveying and Mapping Agency NRW, Stapelfeldt GmbH, Institute of Geodesy and Geoinformation University of Bonn

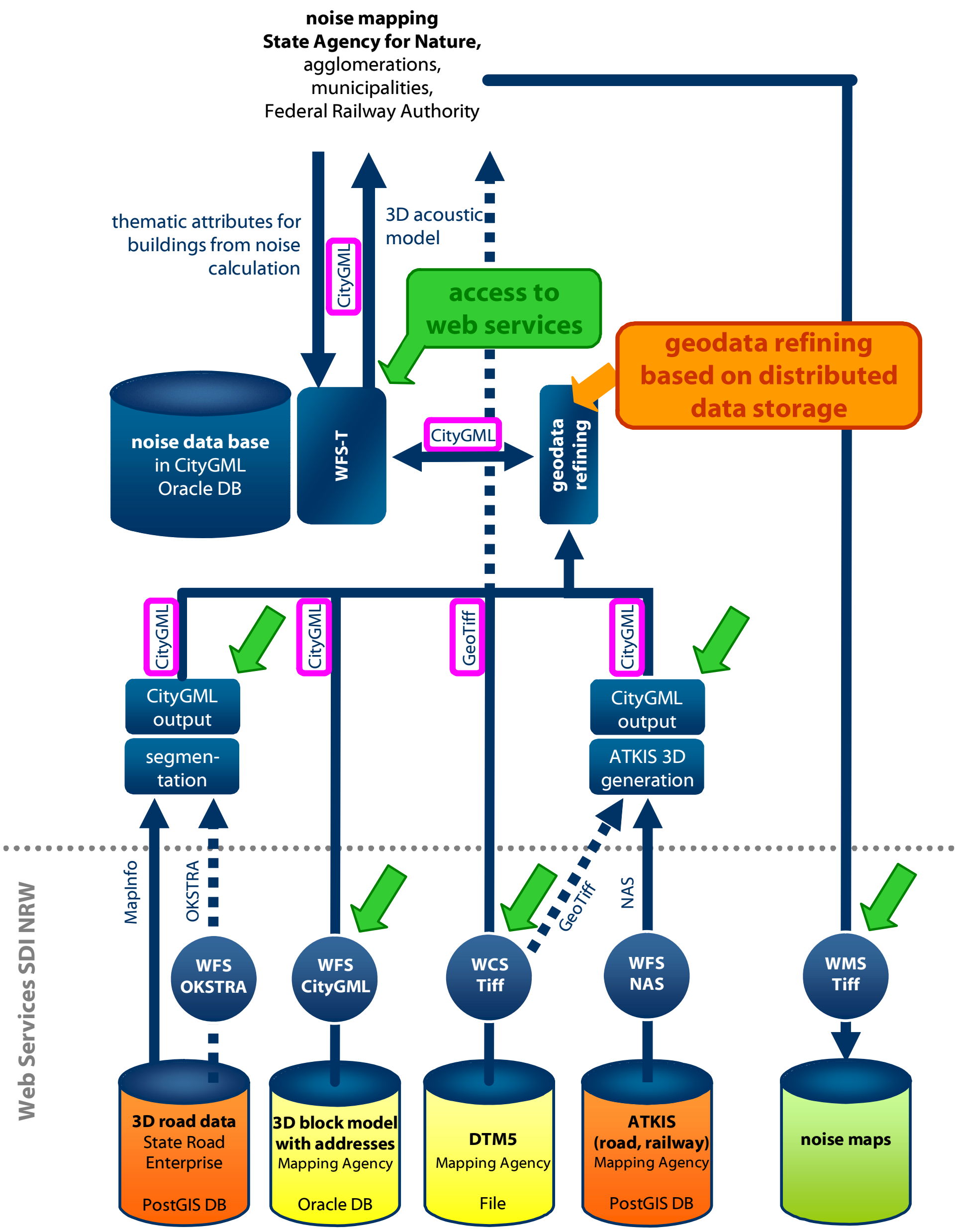
3. ARCHITECTURE: ENLARGEMENT OF THE SDI IN NRW

To provide this considerable amount of statewide 3D geodata, the responsible actors, in particular the State Ministry of Environment, Nature Conservation, Agriculture and Consumer Protection of North Rhine-Westphalia, the State Agency for nature, environment and consumer protection of North Rhine-Westphalia and the Surveying and Mapping Agency of North Rhine-Westphalia, have decided to use the Spatial Data Infrastructure GDI NRW and to extend it with statewide OGC web services.

The reasons for the SDI solution in NRW are obvious: Since five years the 3D modelling standard CityGML has been developed and is now available as specification draft at the Open Geospatial Consortium. Important GIS and software companies are implementing CityGML now as exchange format for 3D geodata. Further more, the GDI NRW has known in the last years a continuous and remarkable development of services and geodata (Sandmann 2005, Brüggemann et al. 2004). Many municipal and federal state geodata are already provided via web services.

The extension of GDI NRW in the context of the EU environmental noise mapping is significant, as it provides for the first time statewide 3D geodata as features in CityGML via OGC Web Feature Services (3D building models in LOD1, 3D road and railway data) and the Digital Terrain Model 10m grid via an OGC Web Coverage Service. For the first time a Web Feature Service for ATKIS road and railway data is implemented in the new AAA-Model (AFIS-ALKIS-ATKIS) with an output interface in CityGML. A CityGML data base is realised, which implements the main features of CityGML in level of detail 0 and 1 (building, transportation, city furniture and terrain model). (Czerwinski et al. 2007)

Figure 5: Enlarged web service architecture of GDI NRW for the implementation of the EU noise mapping
(Graphic: Institute of Geodesy and Geoinformation University of Bonn)



The following web services are realised to provide the 3D geodata mentioned in chapter 2 and Figure 5:

- Basic geodata services
  - The Web Feature Service for 3D block models allows the interoperable and standardised access to the CityGML data base for 3D block models in LOD1.
  - The Web Coverage Service allows the interoperable and standardised access to the DTM 10m grid stored in a file system. It provides 2,5D terrain in GeoTiff format (raster data).
  - The Web Feature Service for ATKIS road and railway data allows the interoperable and standardised access to the according ATKIS data base in the new AAA-Model (AFIS-ALKIS-ATKIS). It provides 3D road and railway features in CityGML LOD0. For CityGML mapping see chapter 4.
  - The Web Feature Service for road data of the State Road Enterprise NRW allows the interoperable and standardised access to the according road data base. It provides 3D road features in CityGML format in LOD0.
- Noise geodata service
  - The transactional Web Feature Service WFS-T for all refined and required 3D noise geodata access to the so called CityGML „noise data base". It provides the data extract from all basic geodata services in CityGML, which are required by the noise immission and had been refined with noise attributes or geometrically homogenised.
- The Web Map Service allows a flexible presentation of the noise maps and immission results for the public. It provides the noise maps in raster format with GetFeature function to query the noise immission at a certain point of interest.

The following workflow based on the above mentioned architecture is realised to perform the noise immission calculation (Figure 5):

- The four basic geodata web services provide the geobasis data as income data for gedata integration and refining.
- The 3D geodata integration and refining accesses to the four basic geodata web services and downloads the required geodata. The advantage is that not the whole data set for the area of NRW has to be downloaded, but that each municipality can be handled one after the other. As the geodata refining is based on distributed data storage and web service provision, a manual data transfer for a huge data volume is avoided. For the geodata integration and refining process/tasks see chapter 5.
- The refined 3D geodata are inserted via the WFS-T into the "noise data base". With respect to DTM and 3D block model, only the additional refined information are inserted, to avoid a double data storage (e.g. attribute reflection for 3D block model, DTM refined as breakline features). The refined

road data are inserted completely, as a re-segmentation and a choice of the required segments had been performed.

- The noise calculation actors (State Agency for nature, environment and consumer protection of NRW, municipalities, Federal Railway Authority) download again all refined and required noise geodata via the WFS-T from the “noise data base”. Additionally, the original DTM and 3D block model geodata are accessed from the basic geodata services. E.g. to get the whole terrain information the WCS is accessed for the original DTM and the WFS-T for additional refined areas given in breakline features.
- The results of noise immission calculation are inserted in the web services again: The noise levels of buildings are inserted via the WFS-T into the “noise data base” and added to the 3D block models (see chapter 5). The spread of noise emission is documented in noise maps via the Web Map Service (noise level in pixels or isophones in isolines).
- The basic geodata services can be used additionally from all affected municipalities to get e.g. the dense railway network from original ATKIS data in 3D for further noise immission processing.

This web service architecture for the purpose of noise mapping poses the following challenges:

- Reading and writing (transactional) web services are necessary.
- The 3D geodata integration and refining is based on distributed data storage and web service provision, as shown above. Thereby, data graveyards in proprietary noise software tools are avoided and instead all affected municipalities can access the refined geodata.
- The noise calculation as well receives the required geodata via web services, as shown above.
- A mix of centralised and decentralised noise calculation processing can be carried out simultaneously: The urban agglomerations > 250.000 inhabitants in NRW can execute their noise calculation decentralised on their own and access all geodata from the web services. The noise immission calculation of major roads, industrial activity sites and major airports in NRW is handled centralised by the State Agency for nature, environment and consumer protection of NRW, which requires the entire refined geodata from the WFS-T.
- The web service architecture must be expandable for the continuation of all geobasis data and the noise calculation results of each 5-years-iteration (e.g. storage of noise attributes from several iterations for the same 3D block model geometry, or update of the 3D block model geometry without loss of the relation to the corresponding noise attributes). Thus, the architecture must serve a sustainable concept.

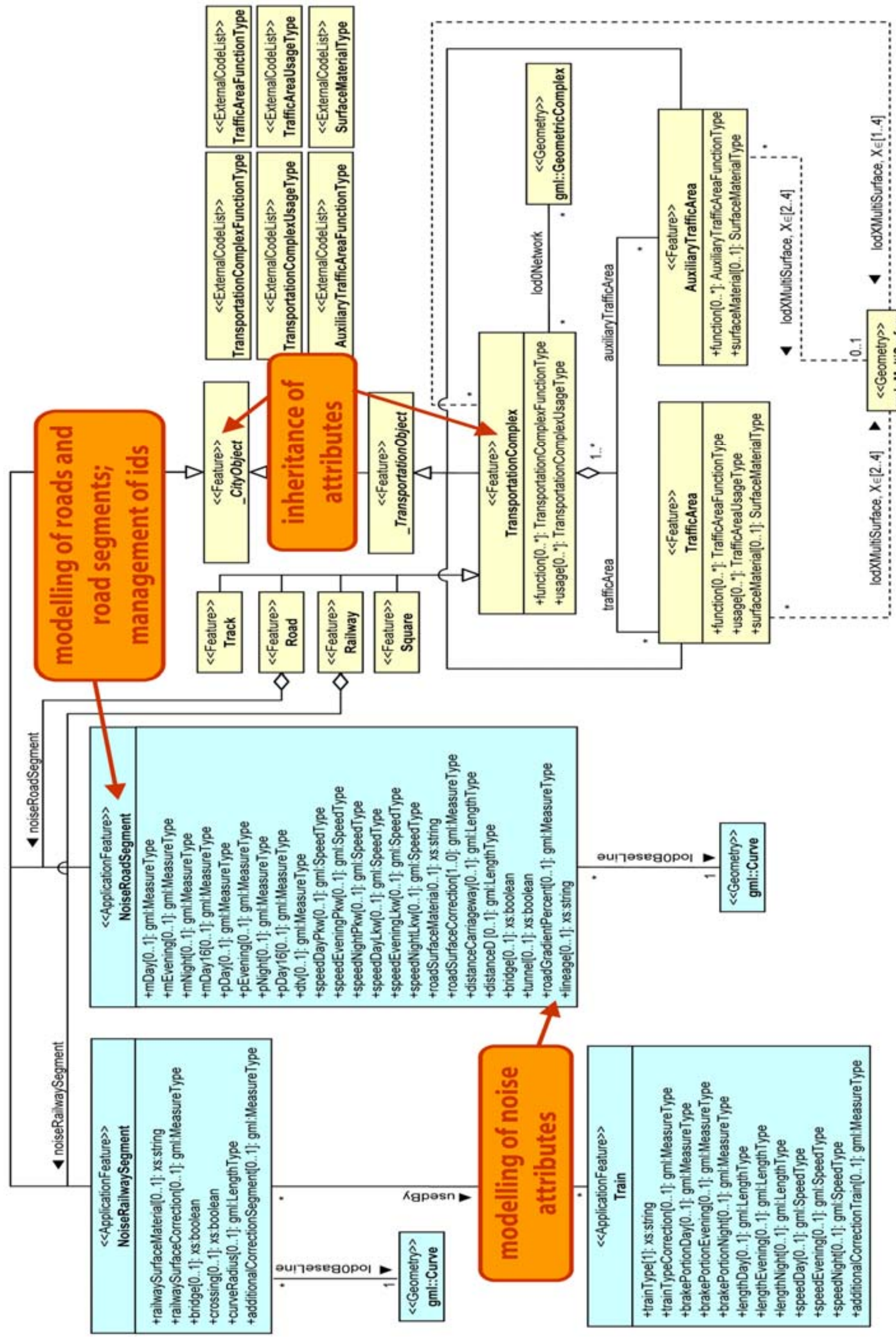
The following specialties are realised:

- There is one single CityGML database realised, which provides the original 3D block models as well as all additional refined noise objects and information (so called “noise geodata base”).
- One Web Features Service is realised to access this database, but with two instances: one for the readonly access to the original 3D block models and one for transactional access (read, insert and update) to the “noise geodata base”.
- In all web services, data bases and transactions the original feature gml:ids from the external referenced information systems is maintained.
- The transactional Web Feature Service provides an asynchronous access interface. This interface is used, if requests expect a huge data volume or if an amount of objects should be handled in the transaction. This asynchronous interface provides and accepts compressed data via gzip.
- The DTM provided via the WCS is stored in a file system, without sheet line system in the coordinate reference system Gauß-Krüger 2. Meridian. The output formats are GeoTiff and ascii data in xyz. The GeoTiff data contain in its header information about location and scaling. They are coded as data type unsigned integer. Thus, the heights are given in decimetres and are added with 1.000m to avoid negative values. Furthermore, a compressed data output is realised as well as an updating tool that allows the WCS write access to update the DTM.
- A data mapping had been realised for ATKIS road and railway data to CityGML as well as for Federal state road data to CityGML (see chapter 4).
- All web services are provided with access protection and safety concept

4. MODELLING: USE OF THE EXCHANGE FORMAT CITYGML

CityGML (City Geography Markup Language) is used as common exchange format between the 3D geodata providing web services and the noise calculation software tools to solve syntactic and semantic interoperability problems (Figure 5). CityGML is XML-based, an application schema of GML3 from the Open Geospatial Consortium and candidate for Best Practice Paper in the OGC (Gröger et al. 2007). CityGML is an open data format for consistent description of 3D city and regional models and allows an interoperable exchange via web services. CityGML represents the geometry, topology, semantics, and appearance of the modelled objects Digital Terrain Model, buildings, transportation, city furniture, vegetation, water bodies and other sites. CityGML defines a multi-scale model with five consecutive levels of detail (LOD0-4).

Figure 6: UML diagram of the CityGML noise application schema (yellow=CityGML basic schema; blue=CityGML noise application schema)
(Graphic: Institute of Geodesy and Geoinformation University of Bonn)



For the special requirements of the noise directive, a CityGML noise application schema has been developed by the Institute of Geodesy and Geoinformation University of Bonn and the Special Interest Group SIG 3D of GDI NRW. It is based on the Application Domain Extension (ADE) mechanism. This mechanism allows the supplementation of existing classes and objects in CityGML (e.g. buildings) by thematic attributes. The quantity as well as the type of these attributes is selectable. As well, the CityGML schema can be complemented by new classes. Hence, the noise application schema contains new objects (e.g. segmentation of roads according to noise requirements – NoiseRoadSegment, Figure 6) as well as noise attributes attached to existing objects (e.g. reflection of buildings). (Czerwinski et al. 2007)

CityGML can be used especially as exchange format for the environmental noise mapping, as the integration and provision of different 2D and 3D geodata is necessary: A flexible integration of DTM and 3D building models with different accuracies and data resources is possible, as well raster terrain model and breaklines. The modelling of road segments and building surfaces is possible to attach thematic noise attributes (e.g. traffic flow, heavy vehicle percentage, speed limit, type of road surface, road gradient, width of a road, reflection). As building surfaces can be modelled separately, the noise immission can be calculated according to each building surface. By the use of semantic aggregation in CityGML, attributes with e.g. cadastral information (function, address) can be inherited from upper CityGML classes/objects like e.g. roads to subclasses like e.g. road segments. Thereby, geodata selection and continuation can be improved. Furthermore, noise related objects like e.g. noise barriers or road surfaces can be modelled in different level of details.

The following geodata from the federal state data providers are mapped to CityGML in the web services:

- ATKIS road and railway data: originally available in the EDBS format (exchange format of ALK and ATKIS data); modelling and provision in CityGML; mapping of 3D heights by intersection with DTM; mapping of ATKIS cadastral information to CityGML (e.g. road name, function, distance of carriageway, see Figure 7 and Figure 8)
- Federal state road data and noise barriers: originally available in MapInfo format; modelling and provision in CityGML; integration and segmentation of different road data sources and thematic road attributes
- Digital Terrain Model: the original DTM is available in ascii data files and had been transformed into GeoTiff required from CityGML and WCS
- 3D block models generated in CityGML see chapter 1

Figure 7: Generation of ATKIS Roads and NoiseRoadSegments in CityGML integrating cadastral information

```
<citygml:cityObjectMember>
  <citygml:Road gml:id="ROAAW0199DZ">
    <gml:name>A59</gml:name>
    …
    <citygml:function>1</citygml:function>
    <noise:noiseRoadSegmentProperty>
      <noise:NoiseRoadSegment gml:id="NRSAW0199DZ001">
        …
        <noise:distanceCarriageway uom="m">15.000000</noise:distanceCarriageway>
        <noise:lineage>ATKIS-LVermA</noise:lineage>
      </noise:NoiseRoadSegment>
    </noise:noiseRoadSegmentProperty>
  </citygml:Road>
</citygml:cityObjectMember>
```

Source: Surveying and Mapping Agency NRW, Institute of Geodesy and Geoinformation University of Bonn

Figure 8: Mapping of ATKIS cadastral road information to CityGML – extract

property/attribute in CityGML	multiplicity	ATKIS source
citygml:Road		
gml:id	1	adv:AX_Strasse/@gml:id
gml:name	0..1	adv:AX_Strasse/adv:bezeichnung
citygml:function	1	adv:AX_Strasse/adv:widmung
citygml:NoiseRoadSegment		
gml:id	1	adv:AX_Strassenachse/@gml:id adv:AX_Fahrbahnachse/@gml:id
noise:distanceCarriageway	0..1	adv:AX_Strassenachse/adv:breiteDerFahrbahn

Source: Surveying and Mapping Agency NRW, Institute of Geodesy and Geoinformation University of Bonn

5. GEODATA REFINING, INTEGRATION AND NOISE IMMISSION CALCULATION

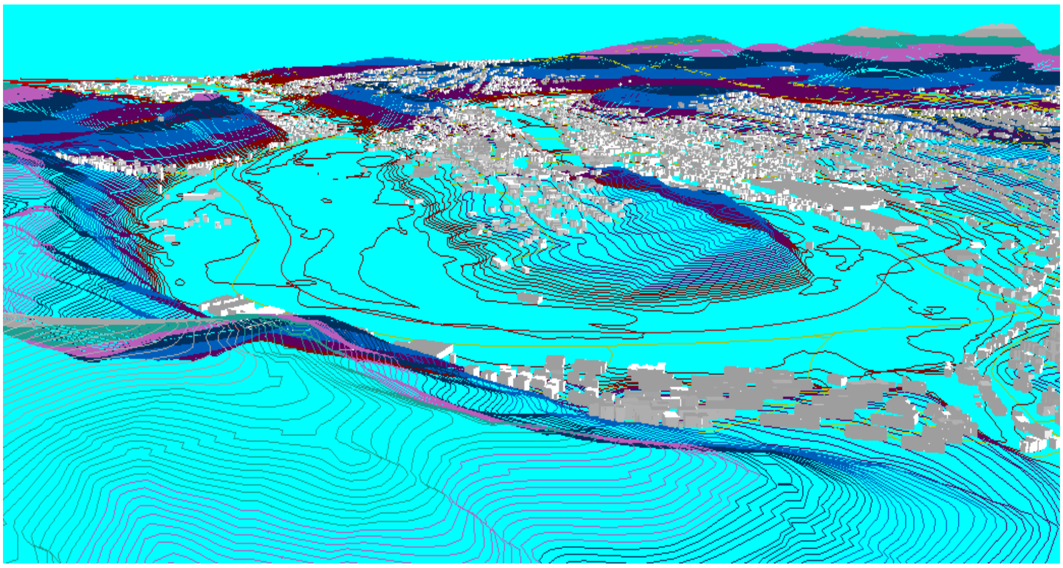
The task of 3D geodata integration is to solve 3D geodata interoperability problems (syntactic, semantic and geometrical interoperability). Since now, mainly 2D interoperability problems had been in the focus of geodata integration. In this project, syntactic interoperability problems (compatibility of different data and file formats) and semantic ones (objects are described differently with respect to thematic or geometric data using different data models) are solved by the use of CityGML. Thematic correction (segmentation of roads, enrichment of noise attributes) and geometrical correction (refinement of the DTM with breaklines, check of 3D geometrical inaccuracy in position of different road geodata to each other or in relation to building outlines) are of concern in the following 3D geodata integration and refinement tasks. (Czerwinski et al. 2006a)

Furthermore, the challenge of the 3D geodata integration and refinement is, that it is based on a distributed data storage and web service provision. The following process is executed (Figure 5): the noise software tool requests the four basic web services and receives the original 3D geodata in CityGML. The refinement tasks are carried out in the noise software. Afterwards, the refined objects and attributes are inserted and updated via the WFS-T into the “noise data base”. The “noise data base” provides the refined 3D noise geodata via the WFS-T for all affected municipalities in NRW. This architecture guarantees the possibility of system continuation and sustainability. Hence, the refinement of the 3D block model with noise attributes as well as of the DTM with breaklines is carried out without any multiple data storage.

The principal 3D geodata refinements in the view of noise mapping are:

- Intersection of DTM 10m grid from the WCS with the noise mapping required segments of road data from WFS owned by the State Road Enterprise (only for motorways and federal state roads in NRW) and of ATKIS road data from WFS owned by the Mapping Agency NRW (all roads in NRW). The goal is to generate terrain cuttings, bridges and tunnels, which are not yet existent in the DTM grid in a high resolution. The DTM is refined with ridge and valley lines as well as breaklines, which are modelled as polyline features in CityGML format. To carry out this task, the DTM can be converted in the noise mapping software into contour lines (Figure 9). Afterwards, the refined breaklines are inserted via the WFS-T into the “noise data base”.
- Integration of the selected required 3D ATKIS road data segments and federal state road data segments in point of view 2D completion and alignment of heights from adjacent segments.
- Check of the 3D geometrical inaccuracy in position of the road data to each other and in relation to the buildings/3D block model outlines from the WFS (e.g. road passes through a building).
- The selected road segments do not have all required noise information/attributes and therefore have to be enriched with according attributes (e.g. traffic flow, heavy vehicle percentage, speed limit. Those integrated and enriched road segments have again to be segmented according to the noise calculation requirements. The same tasks are carried out for noise barriers along the roads.
- The 3D block models are enriched with attributes on reflection properties. Furthermore, the 3D block models are enriched in a second step with the results of noise immission and affected inhabitants.

Figure 9: 3D Geodata in CityGML for the calculation of the noise map in Figure 11: DTM in GeoTiff imported as contour lines to generate CityGML breaklines, 3D block model in CityGML, ATKIS road and railway data in CityGML, federal state road data for higher-level roads in CityGML

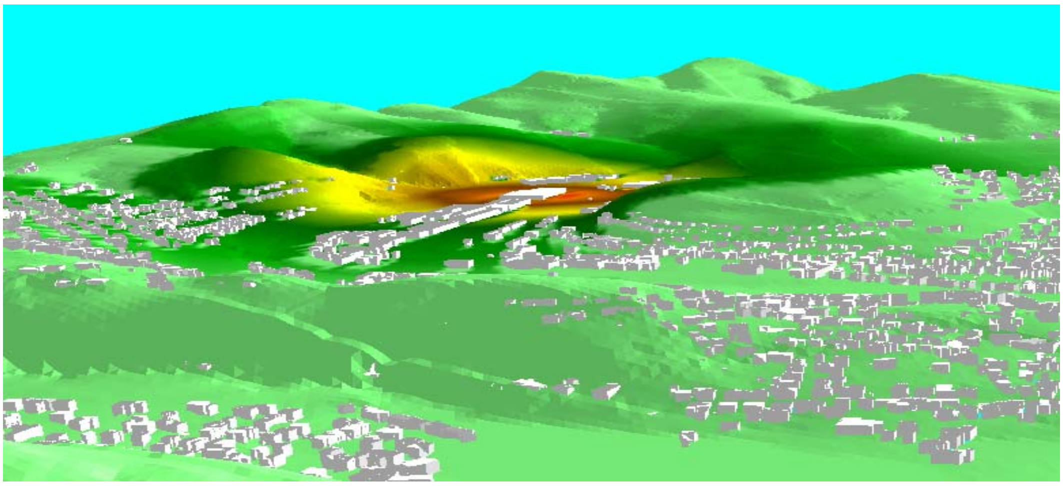


Source: Surveying and Mapping Agency NRW, State Road Enterprise NRW, Stapelfeldt GmbH, Institute of Geodesy and Geoinformation Uni Bonn

The challenge of noise simulation, calculation and mapping is, that the proceeding is carried out almost automatically for each municipality in NRW and that the original required 3D geodata as well as the noise results are downloaded and inserted via the WFS-T in the "noise data base".

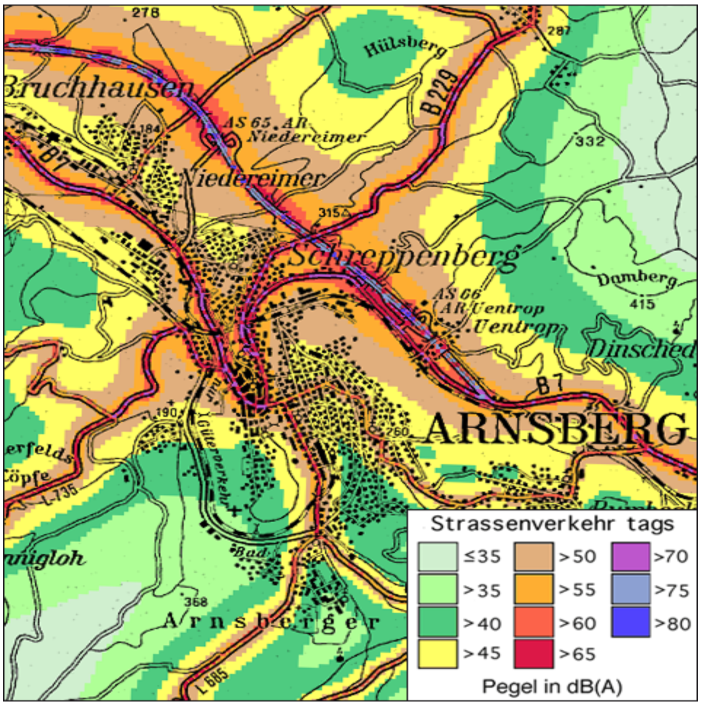
- The automatic noise calculation proceeding implies the download of the refined 3D geodata out of the WFS-T into the noise software, the noise simulation/calculation (Figure 10) in the software concerning the spread in the area and the building surfaces as well as the return of calculation results (noise level of buildings) via the WFS-T into the "noise data base".
- Separately the calculation of statistical information on noise immission is calculated (e.g. affected people and areas).
- The noise maps extracted from the above mentioned noise calculations (Figure 11) are provided via the WMS together with the required reports for the European Union and the public.

Figure 10: Modelling a noise emission source using the 3D CityGML geodata in a special noise calculation software as first step before generating the noise map in Figure 11



Source: Surveying and Mapping Agency NRW, Stapelfeldt GmbH

Figure 11: Noise map generated from the 3D CityGML geodata and used for the reporting demanded of the EU Environmental Noise Directive (dark colours show higher noise immission)



Source: State Agency for nature, environment and consumer protection NRW

6. WEB SERVICE ACCESS AND VISUALISATION

The European Union obligates the EU member states to document the noise immission results in noise maps. The noise maps serve for information to the EU and to the public as well as for action planning of the municipalities. For each noise source (major roads, railways, airports and industrial activity sites) the according noise immission is documented in a separate map (noise level in pixels or isophones in isolines).

According to the Federal Immission Protection Law 2005 (transposition of END into German law) the noise affected municipalities are responsible for the presentation of the immission results. In NRW however the state authority, represented by the State Ministry of Environment, Nature Conservation, Agriculture and Consumer Protection of NRW and the State Agency for Nature, Environment and Consumer Protection of NRW, supports the municipalities and provides the results via the portal www.umgebungslaerm.nrw.de (Stöcker-Meier et al. 2007). Since now, this presentation structure for EU environmental noise mapping is singular in Germany. The portal contains the following noise calculation results and required 3D geodata:

- Visualisation of noise calculation results in form of noise maps in a Web Mapping Client with selection possibilities for all affected municipalities, corresponding extract of the noise immission report to the EU and links to the respective municipality
- Download of noise calculation results in form of noise maps according to the respective municipality and the noise sources
- Download of the original and refined 3D geodata, which are required for the noise immission calculation, in the CityGML format according to the respective municipalities and the noise sources. This is realised by a Web Feature Service access via a subpage of the geobasis data portal NRW (Geobasisdatenportal NRW www.geobasis.nrw.de).

The visualisation and download of noise immission results and required 3D geodata considers the customer needs (citizens, actors of noise calculation, decision makers in politics and business). The Web Map Service offers a flexible and comfortable presentation of the noise immission results for the public, as different extracts or the synopsis with further topographical maps of NRW and city maps of the affected municipalities are possible.

An additional possibility to visualise the 3D geodata provided by the web services in CityGML is the so called “Aristoteles Viewer”, an open source user interface developed by the Institute of Geodesy and Geoinformation, University of Bonn (Aristoteles 2007). The speciality of Aristoteles is its access function to WFS and

WCS as well as its visualisation of XML and GML data. This viewer is used in the project to detect interoperability problems and inconsistencies of the provided 3D geodata (e.g. geometrical offset of two road objects, errors of 3D block model heights, integration of 3D block models and DTM). (Czerwinski et al. 2007)

7. SUMMARY AND OUTLOOK

This article shows a very ambitious project to perform the EU noise mapping based on a web service architecture. In the first iteration of noise mapping in 2007 a lot of issues are faced, like e.g. the transactional Web Feature Service or the mapping of ATKIS road data to CityGML. As well, many challenges had to cope with, e.g. the great amount of 3D geodata in the data bases, the 3D geodata refining based solely on web service access, the semantic homogenisation and provision of all 3D geodata in CityGML format and in addition the short implementation time of about one year. As presented in chapter 3, this project shows an advanced complexity of web service infrastructure in comparison with other SDI project, e.g. in Berlin (Döllner et al. 2006).

At the beginning, performance problems arised with the transactional Web Feature Service, as there are more than 20 million features of CityGML buildings in the associated Oracle data base. We solved the problem by the implementation of a high level web service application and the improvement of the techniques: optimisation of Oracle CityGML data base by combining tables, reduction of joins in the SQL statements of the web service requests, augmentation of hardware resources to about 32 GB random access memory. Hence, there is the possibility now to download a city like Cologne (426.235 buildings, 30x33km²) from the WFS 100 times faster than before. The other readonly web services of road data and DTM reach again an even higher performance.

The mapping of ATKIS road data and federal state road data to 3D CityGML format on the fly in the web service works very well and results in semantic homogenisation of the different road sources. The provision of all 3D geodata via the web service CityGML output interfaces was successful and allows to visualise and process the various 3D geodata in the noise software and other applications or viewers like Aristoteles.

In 2008 during the preparation of the next noise mapping iteration there are further tasks to solve in the architecture. This concerns mainly the continuation of geometric and thematic noise data without any information loss. This implies e.g. a query logic of the WFS-T, a follow up of geodata modifications, time stamps or the storage of versions. The project conception considers these future adjustments already now, as it contains global unique identifiers (gml:id) that persist during all transactions, data references to their origin information systems and the linkage to further cadastral information like address, building identifier ("Gebäudekennzeichen") and function.

As well, the change of the coordinate reference system to ETRS89/UTM will be a task of the next iteration.

Last but not least, the adaptation to the new EU Directive on INSPIRE has to be considered, as the requirements of the INSPIRE implementing rules are still in progress. However, NRW provides already at present an implementation example for INSPIRE. Huge statewide environmental geodata are provided via OGC Web Feature Service, Web Coverage Service and Web Map Service using a single xml/gml-based modelling and exchange format. The implemented geodata refer to some of the themes listed in Annex I-III of the directive and originally belong to federal state agencies. These geodata and web services are provided for the use in environmental and nature protection tasks in the whole administration of environmental affaires in NRW, concerning ministries, agencies and municipalities. For the purpose of noise mapping, the use of geodata and services is free of charge. The implementation of the web services has been connected to the regional spatial data infrastructure GDI NRW to allow a broader use in further applications. The provision of these geodata and services is as well possible in portals of the German spatial data infrastructure GDI-DE in the context of INSPIRE implementation.

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