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Interoperability and accuracy requirements for EU environmental noise mapping

Angela Czerwinski[1], Thomas H. Kolbe[1], Lutz Plümer[1], Elke Stöcker-Meier[2]

[1] Institute for Cartography and Geoinformation, University of Bonn,
Meckenheimer Allee 172, D-53115 Bonn,
{czerwinski|kolbe|pluemer}@ikg.uni-bonn.de

[2] State Ministry of Environment, Nature Conservation, Agriculture
and Consumer Protection of North Rhine-Westphalia,
Schwannstr. 3, D-40476 Düsseldorf,
elke.stoecker-meier@munlv.nrw.de

Abstract. The use of geoinformation in the environmental sector got a new challenge by the commencement of the EU Environmental Noise Directive 2002/49/EG (END) in 2002 and its transposition into German law (§ 47 a-f of Federal Immission Protection Law) in 2005. The EU environmental noise mapping puts high demands on the access, availability and accuracy of numerous thematic and geographical information in 2D, 2.5D, and 3D.
A recently conducted study showed, that financial savings in the context of environmental noise mapping of approx. 60% of the total can be reached both by using the appropriate level of geodata accuracy and by the sustainable use of geoinformation in the context of Spatial Data Infrastructures (SDI). Interoperability of standardised web services (OGC, ISO) meets the requirements of a flexible use of geodata for noise mapping tasks.
In our contribution, we will discuss how different strategies for environmental noise mapping are facilitated by the consequent application of Spatial Data Infrastructure techniques.

Keywords. noise mapping, spatial data infrastructure, SDI, CityGML

1 Introduction

The EU Environmental Noise Directive (END) obligates the EU member states to map environmental noise in urban agglomerations, along main roads and main railways, and in the surroundings of major airports as well as to draw up action plans [8], [9]. Furthermore, an obligatory schedule is prescribed including a revision in a 5-years frequency. In Germany the municipalities are initially responsible for the environmental noise mapping (except for railways in federal ownership). 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. [7]

To evaluate the conditions of noise mapping in North Rhine-Westphalia, the state of Germany that is mostly affected by the END, a feasibility study was conducted by the Institute for Cartography and Geoinformation of the University of Bonn on behalf of the State Ministry of Environment, Nature Conservation, Agriculture and Consumer Protection of NRW [12]. The complex responsibility structure for noise mapping in NRW and in Germany requires a flexible implementation of decentralised and centralised components, which might be of special interest for other actors in the EU as well.

NRW is mostly affected by the END because of its high amount of agglomerations (12 > 250.000 habitants, ~60 > 100.000 habitants), responsible municipalities (384 of 396) and number of exposed people. The main geodata, which have to be integrated for noise mapping, will be: Digital Terrain Model 5m grid, 3D block model LOD1, ATKIS road and railway data, state road traffic data, railway data of German Railway, address data [5]. These geodata are provided in NRW at different sources and formats, which complicates their provision and integration.

2 Initial reflections

At the beginning of research two different options for technical and organisational geodata processing in environmental noise mapping were at disposition in NRW. These options were approved in the feasibility study, if they are suitable for noise mapping in respect of due time, due professional requirements, cost-efficiency and sustainability.

The two alternative options were either a completely decentralised processing, where all concerned municipalities would execute the implementation and noise computation, or a completely centralised processing by a central unit. The structure of the decentralised processing was derived from the responsibilities given in the END (Fig. 1, 2).

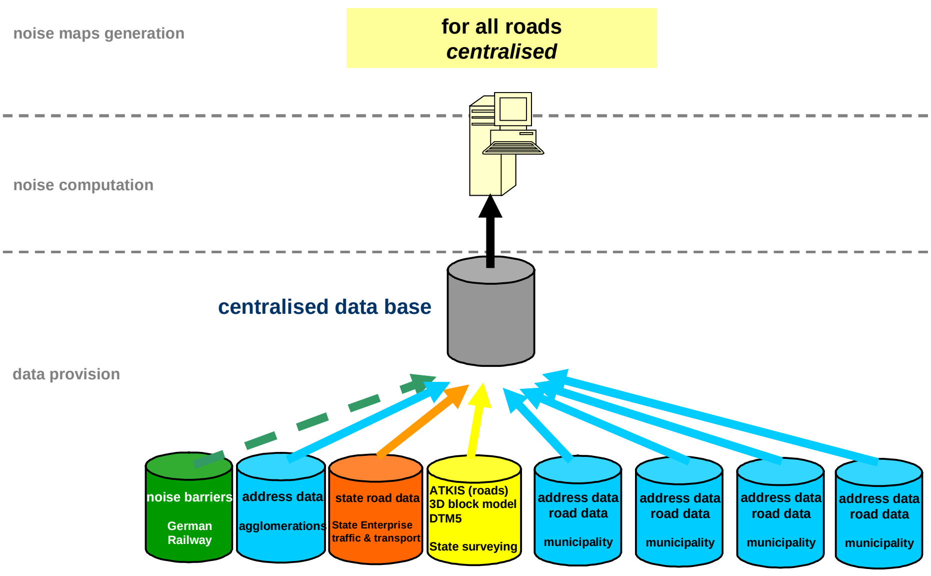


Fig. 1. Centralised option for geodata processing in environmental noise mapping in the domain of road traffic noise (graphic: IKG Uni Bonn).

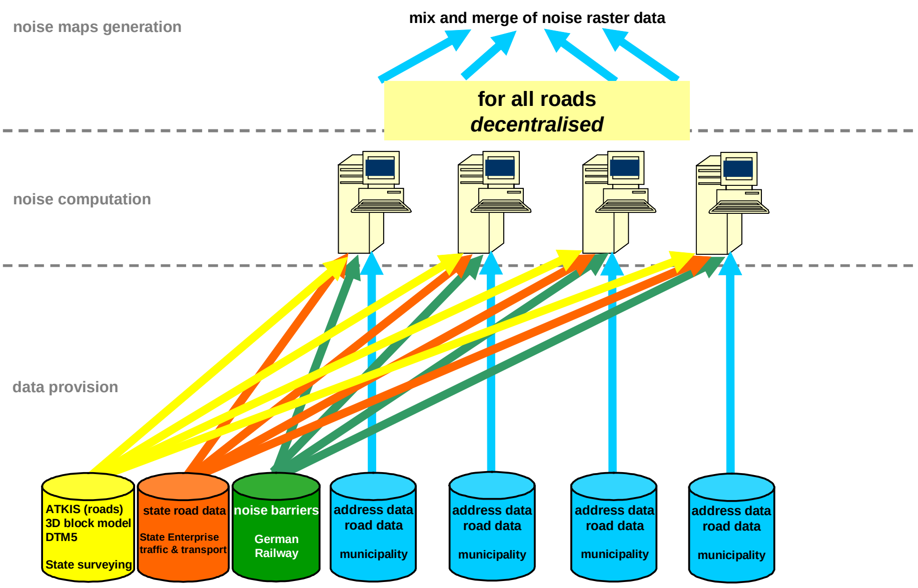


Fig. 2. Decentralised option for geodata processing in environmental noise mapping in the domain of road traffic noise (graphic: IKG Uni Bonn).

3 Time and cost reduction as benefit

For the verification of the initial options, especially the centralised and decentralised ones, all concerned actors had been interviewed selecting representative examples (municipalities and state authorities, consultants and software companies, organisations and working groups). The interview was based on experiences of the actors concerning previous noise mapping as well as on estimations of the forthcoming environmental noise mapping. Results of the analysis were the following expenditures of time and finance and their savings concerning the different kinds of noise.

The acquisition, processing and integration of geodata in a municipality demanded the highest expenditure of time with 90% of the total volume so far (Fig. 3) [12]. The homogenisation and processing of (3D) geometric data required a major amount of 36% of the total. Another high expenditure was necessary for the thematic data acquisition of road traffic (17% of the total) and industrial activity sites (15% of the total). Mostly, the reason for the high expenditures of time is the lack of geodata in smaller municipalities < 250.000 habitants (Fig. 4). Using statewide available geodata in a decentralised option instead, high administration effort will be caused for the geodata distribution from state data holders to all responsible municipalities (e.g. 384 of 396 in NRW).

A result of the study was, that savings of time can be made in the domains of 3D geodata acquisition, main road traffic and industrial activity sites, if using Spatial Data Infrastructures (SDI) for noise mapping in a differentiated strategy instead of an entirely centralised and decentralised option (chapter 5). Especially, the use of the existing state SDI structures (e.g. Geodata Infrastructure GDI NRW [4]) and their extension will cause remarkable benefits. Mainly, savings in time can be made by the centralised provision of statewide available 3D geodata via SDI (Digital Terrain Model 5m grid, 3D block model LOD1, ATKIS road and railway data, state road traffic data) and the centralised processing of main road traffic > 3 million vehicles per year outside of urban agglomerations > 250.000 habitants.

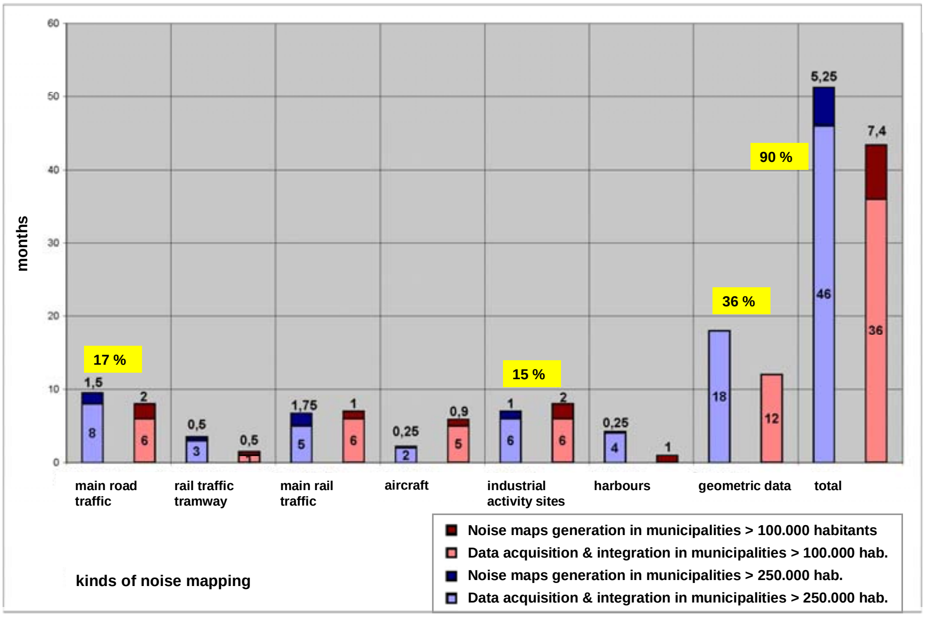


Fig. 3. Expenditure of time for geodata acquisition and noise mapping shown for two different municipalities. Highest expenditures demand 3D geodata provision, road traffic and industrial activity sites (graphic: IKG Uni Bonn).

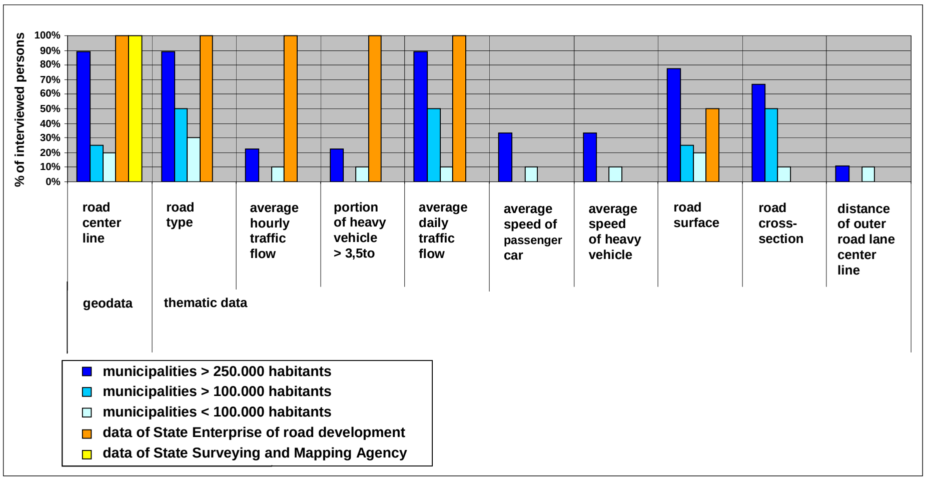


Fig. 4. Available geodata in the domain of road traffic at municipalities >250.000, >100.000 and <100.000 habitants as well as at the State Surveying and Mapping Agency and the State Enterprise of road development (graphic: IKG Uni Bonn).

Regarding the financial expenses for noise mapping the following results can be stated: The financial expenses for the differentiated strategy for environmental noise mapping including a coordinated processing and the use of SDI structures will be much lower than those expenses, which will arise applying the decentralised option (Fig. 5). In total, financial savings of about 60 % of the total costs can be made. [12]

As the highest financial expenses arised for data acquisition and integration so far, the highest saving potentials can be made in 3D geodata provision with 27,6 % of the total costs and 77% of the sectoral costs. The savings are caused by the use of SDI structures, interoperable interfaces and sustainable geodata acquisition and storage for the provision of statewide 3D geodata. Another notable part of savings can be realised in the noise mapping of industrial activity sites by the implementation of simplified calculation methods (90% of sectoral costs). Furthermore, remarkable savings of 50% of sectoral costs can be made in the sector of main road traffic, if the road traffic geodata are provided centralised for all main roads > 3 million vehicles per year and the environmental noise mapping is processed centralised for all main roads outside of the urban agglomerations. The savings in the sector of aircraft noise around airports can be around 60% of sectoral costs, if only one complete noise mapping for each airport is generated instead of partial mappings for each concerned municipality. Further savings of 50% of sectoral costs can be made using estimated values for the investigation of the number of exposed people outside of urban agglomerations < 100.000 habitants. Detailed population data of all concerned smaller municipalities do not have to be collected and integrated (384 municipalities in NRW). [7]

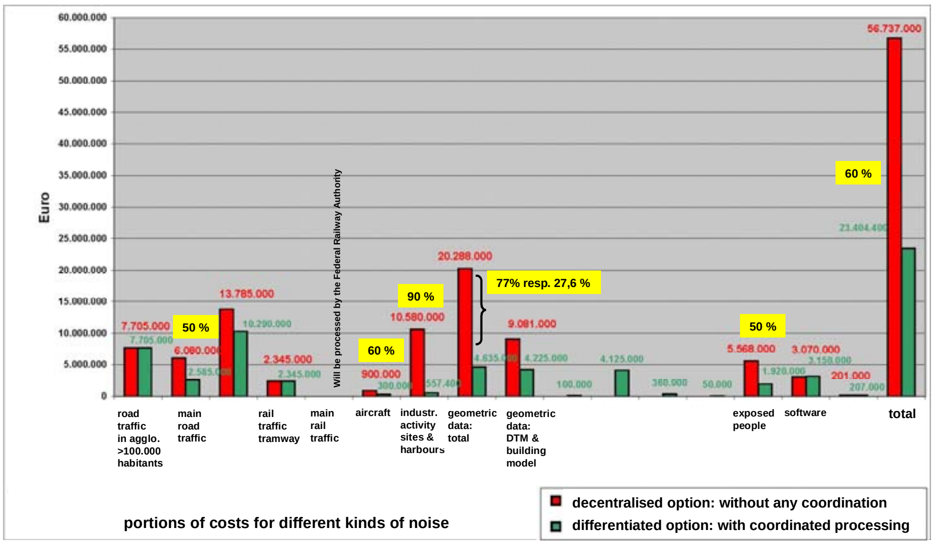


Fig. 5. Financial expenses and savings (yellow box) for the differentiated option of environmental noise mapping including a coordinated processing (green) and for the decentralised option without any coordination (red) (graphic: IKG Uni Bonn).

Especially, an efficient bundling of noise mapping tasks will contribute to a reduction of data streams and expenditure of time and finance. This bundling could be realised by the data provision via web services, particularly for 3D statewide available geodata (Digital Terrain Model 5m grid, 3D block model LOD1, ATKIS road and railway data, state road traffic data) [1] [13].

4 Problems of interoperability

Another result of the study was the quantification of the costs for geodata integration caused by the use of different data models, accuracies and techniques for the extraction of 3D geodata, especially of 3D building models [12]. Especially a completely centralised or decentralised option of noise mapping evoke high interoperability problems. The following interoperability problems can be observed: Problems of syntactic interoperability arise, if the compatibility of different data and file formats is not assured, e.g. files of municipal geographical information systems cannot be imported in noise mapping software programs or converted to their proprietary format [3]. Problems of geometrical interoperability result from geometric data, which do not match together spatially and cause inaccuracy in position, e.g. of roads and buildings to each other (road passes through a building). Problems of semantic interoperability arise, if objects are described differently with respect to thematic or geometric data using different data models, e.g. different definitions of the same road section in different data sets.

An example of geometrical interoperability problems is shown in Fig. 6: geometrical inaccuracy in position of different road geodata (red and blue) in relation to building outlines (yellow) causes errors in noise mapping calculations and has to be homogenised.

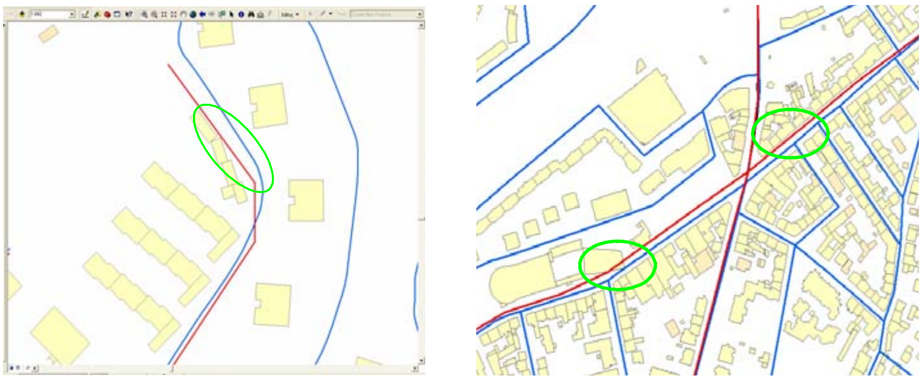


Fig. 6. Road geodata of two different administrations (red and blue) show geometrical interoperability problems (graphic: IKG Uni Bonn).

An example for semantic interoperability problems is shown in Fig. 7: geometric data of one data provider has a different description of the road sections from the thematic data of another data provider. Thus, the integration of geometric and thematic geodata causes errors and the geodata have to be homogenised.

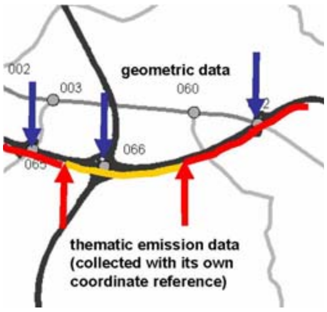


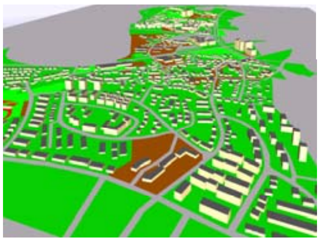
Fig. 7. Geometric (blue) and thematic data (red, yellow) show semantic interoperability problems (source: State Enterprise of road development, graphic: IKG Uni Bonn).

A solution for syntactic interoperability problems will be the use of GML (Geography Markup Language) as an interoperable geodata exchange format [6]. The new extended CityGML modelling language for 3D geodata storage and exchange will be an answer to semantic interoperability problems [10] [11].

The use of CityGML in geodata integration has the following advantages: CityGML is an open data format for consistent description of 3D city and regional models and allows an interoperable exchange via web services. CityGML is XML-based and an application schema of GML3 from the Open Geospatial Consortium [6]. 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) [7].

CityGML can be used especially 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 will be possible. The modelling of e.g. noise barriers and road surfaces can be achieved using generic objects and attributes of CityGML (Fig. 8). Thus, CityGML can become the geodata exchange interface between noise mapping software and data providers, and only one single exchange format will be necessary.

In addition, consistent geodata generation techniques should be applied, e.g. to generate 3D building models not in a single noise mapping software but at the original data provider, like the State Surveying and Mapping Agency or the cadastral office of a municipality. Furthermore, the linking of thematic data attributes and geometric data should always be considered. Thematic data attributes should not be collected with their own geometry, as this may cause time-consuming and expensive problems of data integration.



3D block model (LOD1)

Integration of road and railway (LOD2)

Road surface (LOD2)

Noise barriers and bridges (LOD2)

Fig. 8. CityGML modells 3D objects, which will be necessary especially for the environmental noise mapping (source: Rheinmetall Defence Electronics, District of Recklinghausen, City of Solingen).

5 Differentiated strategy for flexible noise mapping using SDIs

As described above, the implementation of the END causes not only organisational problems, but also technical ones, which provoke high financial expenses. Financial expenses and interoperability problems are mainly caused applying the completely decentralised or centralised strategy. It was also identified, that not one of these strategies will be appropriate to be realised for all kinds of noise, but that each kind of noise needs its suitable strategy. Hence, a differentiated strategy depending on the kinds of noise appears as the most effective one, especially regarding the existing geodata and the use of a Spatial Data Infrastructure [12]. The differentiated strategy implies thus a mix of centralised and decentralised elements, of regional and thematic bundling of noise mapping processing. The differentiated strategy concerns both the ingoing geodata of noise calculation and the outgoing generated noise maps (Fig. 9). However, a centralised processing does not necessarily mean the use of a central database solution. We propose a bundling of data provision and noise calculation in the cost-intensive domains, where competences for an appropriate processing of the END in due time is missing. A differentiated strategy does as well mean a flexible integration of the urban agglomerations. I.e. the agglomerations can process the noise mapping decentralised on their own using the provision of state geodata via Spatial Data Infrastructures, and the small municipalities along main roads are discharged through a centralised processing. A Spatial Data Infrastructure will allow a flexible use and provision of the required (3D)geodata (7day/24hours). The specialty of a SDI is the data provision via distributed data storage and web services according to OGC/ISO standardisation (Web Map Service, Web Feature Service, Web Coverage Service). The web services for noise mapping should be integrated in the existing structures of the regional or national SDI, e.g. GDI NRW, GDI-DE, INSPIRE [4] [13] [2].

A differentiated strategy should consider as well the requirements for homogenisation and integration of 3D geodata. It determines also the requirements for a sustainable continuation of the original geodata and the workflow of data access (protocol, synchronisation).

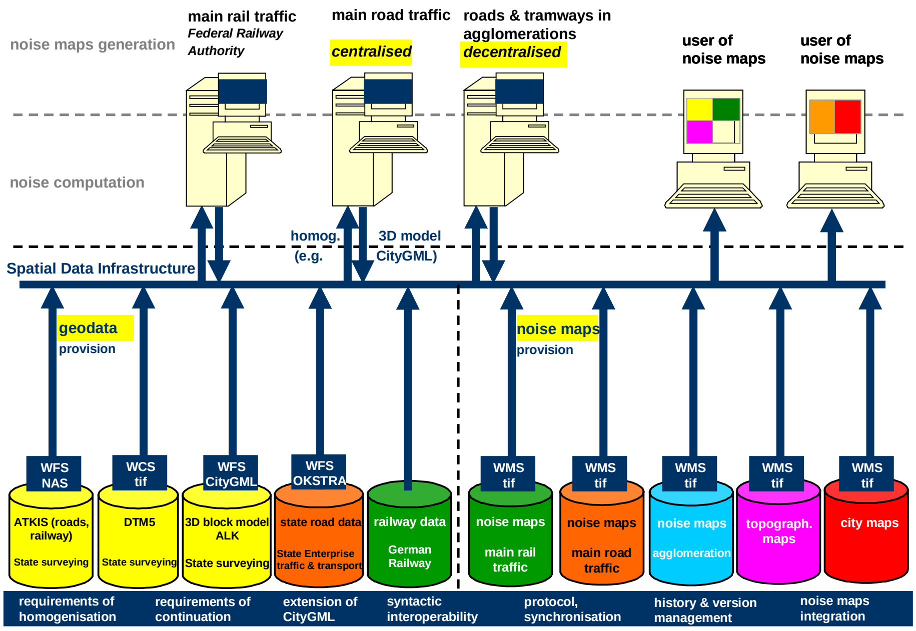


Fig. 9. Implementing the environmental noise mapping in a Spatial Data Infrastructure for ingoing geodata and generated noise maps. The differentiated strategy allows a flexible geodata use for decentralised and centralised realisation components (graphic: IKG Uni Bonn).

5.1 SDI for ingoing geodata

A SDI allows the provision of ingoing geodata for noise mapping, which are of interest to all actors (Digital Terrain Model 5m grid, 3D block model LOD1, ALK, ATKIS road and railway data, state road traffic data, railway data of German Railway). These geodata will allow the use of coherent geobasis data (Fig. 9, 10). The provision of these geodata via SDI is important to reach the shown financial savings and a sustainable data continuation. These geodata will remain at their original data providers and be transmitted via Web Feature Services or Web Coverage Services to the different centralised and decentralised noise calculators. As all distributed geodata show different formats and interoperability problems, the special challenge will be the transmission of a homogenised and integrated landscape model of all geodata to the noise mapping programs. A standardised, interoperable interface format, like e.g. CityGML, will be necessary to allow the transmission of the mentioned geodata from all data provider to the noise mapping programs without conversion efforts. CityGML will be suitable for this interface format, especially as it allows a geometric, topologic and semantic modelling. A finally automated data homogenisation component will be required to integrate DTM, ATKIS data and building model as well as to eliminate their geometrical and semantic interoperability problems.

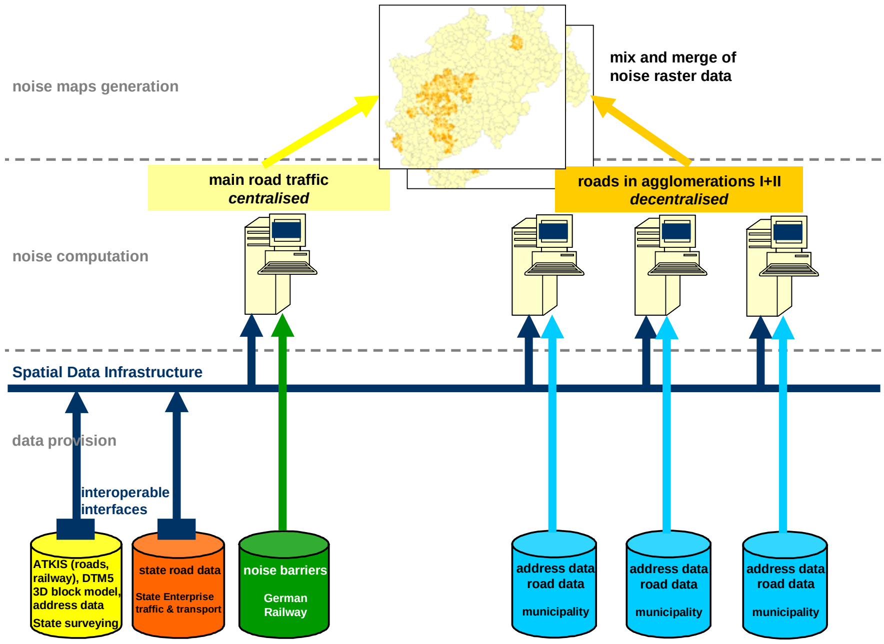


Fig. 10. A differentiated strategy for the noise mapping of roads uses a Spatial Data Infrastructure for the main ingoing geodata as well as decentralised and centralised realisation components (graphic: IKG Uni Bonn).

5.2 SDI for generated noise maps

On the other hand, a SDI can be used as well for the provision and distribution of the generated noise maps from the noise mapping programs to the final users (Fig. 9). As the requirements and purposes of the final users in economy, administration, science and the public are very distinct, the access method should be as well very flexible.

Aspects of cartographic design and presentation should be considered to increase a clear interpretation and the acceptance of the public. Especially the well-known Web Map Service (WMS) plays a major role in collecting and presenting the generated noise maps to the public. The particular advantage of a WMS is, that the numerous noise maps worked out for all kinds of noise by different responsible actors throughout the country can flow back via the interoperable interface to the SDI and there can be viewed in an integrated aspect, flexible resolution and extract according to the special end user interests. Furthermore, the generated noise maps can be combined with other topographical or city maps according to the required purpose [12]. As well, several noise maps can be integrated using the raster calculation method, e.g. the road noise maps from urban agglomerations and beyond them. Nevertheless, a coherent format for the generated noise maps has to be defined and a consistent geo-referencing has to be applied. As coherent format we recommend the tif-format, as it allows the representation of pixel values in terms of db-values. The provision of the generated noise maps via WMS is of special interest for all kinds of noise and has to be discussed in a broader field, e.g. in the GDI-DE.

5.3 Integration in one SDI structure

Both the SDI system of ingoing geodata and that of generated noise maps can be integrated, represented and realised in one single SDI structure (Fig. 9). Thereby, different geodata provider and user benefit from the same SDI. E.g. the noise calculators use the ingoing geodata and supply afterwards their generated noise maps back in the SDI system. These noise maps again can be applied from different end user for the elaboration of Noise Action Plans.

6 Outlook

In this article we showed that environmental noise mapping will be facilitated and sustainably cost-efficient by the consequent application of Spatial Data Infrastructure techniques. This concerns both the technical as well as the organisational point of view. The benefits in time and cost reductions provoked by the use of SDI structures in noise mapping will be higher than the financial expenses for the extention/implementation of new required SDI elements. SDI services and geodata implemented for the END can be re-used later on in further environmental questions. Furthermore, the selection of appropriate accuracies for geodata acquisition as well as the adjustment of geometrical, syntactic and semantic interoperability will contribute to an efficient noise mapping of high quality.

An interaction and cooperation at federal level will be necessary to benefit from the advantages of SDI structures in all German states, e.g. for the provision of generated noise maps. Therefore, the definition and testing of appropriate formats and extracts, the visualisation combined with federal geodata as well as the raster calculation has to be worked out and approved. As well, the national OKSTRA data catalogue has to be checked concerning the requirements of the END and if necessary, some object descriptions have to be adapted, e.g. noise barriers or road surfaces. Furthermore, it might be sustainable and cost-efficient to provide all statewide and federal geodata used for noise mapping (DTM, 3D block models, ATKIS data, state road data) via web services for the use of further iterations and for the noise computation of federal main railway.

References

1. Altmaier, A., Kolbe, T.H.: Applications and Solutions for Interoperable 3d Geo-Visualization, in: Fritsch, Dieter (eds.): Proceedings of the Photogrammetric Week 2003, Stuttgart (2003)
2. Bernard, L., Annoni, A., Kanellopoulos, I., Millot, M., Nogueras Iso, J., Nowak, J., Tith, K.: What does INSPIRE need? – Development and research requirements, in: Proceedings, 8th AGILE Conference on GIScience, Estoril (2005)
3. Bishr, Y.: Overcoming the semantic and other barriers to GIS interoperability, in: International Journal on Geographical Information Science, 12(4) (1998)
4. Brüggemann, H., Sandmann, S., Riecken, J.: The GDI.NRW as a component of the German, European and Global Spatial Data Infrastructure, in: Proceedings, GSDI-conference 2004, Bangalore (2004)
5. Busch, A., Willrich, F.: Quality management of ATKIS data, in: Proceedings of OEEPE/ISPRS Joint Workshop on Spatial Data Quality Management, Istanbul (2002)
6. Cox, S., Daisy, P., Lake, R., Portele, C., Whiteside, A.: OpenGIS Geography Markup Language (GML 3.1), Implementation Specification Version 3.1.0, Recommendation Paper, OGC Doc. No. 03-105r1 (2004)
7. Czerwinski, A., Kolbe, T.H., Plümer, L., Stöcker-Meier, E.: Spatial data infrastructure techniques for flexible noise mapping strategies, in: Tochtermann, K., Scharl, A. (eds.): Proceedings of the 20th International Conference on Environmental Informatics - Managing Environmental Knowledge, Graz (2005)
8. European Union (eds.): Directive 2002/49/EG of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise [END], in: Official Journal of the European Communities from 18.7.02.
9. Federal Government of Germany (eds.): Gesetz zur Umsetzung der EG-Richtlinie über die Bewertung und Bekämpfung von Umgebungslärm vom 24. Juni 2005, in: Bundesgesetzblatt Jg. 2005, Teil 1, Nr. 38, Bonn 29.6.05, Internet: http://217.160.60.235/BGBL/bgbl1f/bgbl105s1794.pdf.
10. Gröger, G., Kolbe, T.H., Czerwinski, A.: OpenGIS City Geography Markup Language (CityGML), Implementation Specification Version 0.3.0, Discussion Paper, OGC Doc. No. 06-057 (2006)
11. Kolbe, T.H., Gröger, G., Plümer, L.: CityGML - 3D City Models for Emergency Response, to appear in: Geoinformation-Technology for Emergency Response, ISPRS book series, Taylor & Francis (2006)
12. Plümer, L., Czerwinski, A., Kolbe, T.H.: Machbarkeitsstudie zur Umsetzung der EU-Umgebungslärmrichtlinie in NRW, Bonn (2006), Internet: http://www.munlv.nrw.de/sites/arbeitsbereiche/immission/umgebunglaermricht.htm
13. Sandmann, S.: TIM-online - a part of the egovernment strategy by the Federal State North-Rhine Westphalia, in: Proceedings, 8th AGILE Conference on GIScience, Estoril (2005)