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Natural Hazards and Earth System Sciences

CEDIM Risk Explorer – a map server solution in the project "Risk Map Germany"

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Abstract. The project "Risk Map Germany" at the Center for Disaster Management and Risk Reduction Technology (CEDIM) aims at visualizing hazards, vulnerabilities and risks associated with natural and man made hazards. CEDIM as an interdisciplinary project unified various expertise like earthquake, storm and flood disaster research. Our aim was to visualize the manifold data exploration in thematic maps. The implemented Web-GIS solution "CEDIM Risk Explorer" represents the map visualizations of the different risk research. This Web-GIS integrates results from interdisciplinary work as maps of hazard, vulnerability and risk in one application and offers therefore new cognitions to the user by enabling visual comparisons. The present paper starts with a project introduction and a literature review of distributed GIS environments. Further the methods of map realization and visualization in the selected technical solution is worked out. Finally, the conclusions give the perspectives for future developments to the "CEDIM Risk Explorer".

1 Introduction

1.1 Risk atlas as an output of the project "Risk Map Germany"

The main aim of the project "Risk Map Germany" in the Center for Disaster Management and Risk Reduction Technology (CEDIM) is to generate risk maps associated with natural and man made hazards in Germany. Different risks were to be analyzed, compared and finally synoptically visualized in form of cartographic presentations. Within CEDIM, risks due to the natural threats earthquakes, flooding and windstorms as well as man-made risks have been investigated.

The research revealed a range of results such as vulnerability, hazard and risk maps of the different threats at different spatial scales. In order to consolidate the project results in a consistent way, a uniform accurate cartographic style was to be developed and the various maps were to be represented to the public in an atlas. It was decided to publish an electronic atlas using the Internet and in doing so reach a variety of users at low costs. Our research work is focused on the possibility of a synoptical representation of the generated thematic maps. Therefore, this paper presents the results of a working group whose aims were

1. formulating proposals for the cartographical visualization of different themes,

2. compiling the CEDIM results and classification in map themes, and

3. implementing a technical solution for the online map publication that allows the user to compare different risks.

The paper is organized as follows: At first, an introduction of GIS applications for the Internet especially for the World Wide Web (WWW) and mapping application with a focus on disaster and risk management is given. Section 2 discusses different methods of cartographic visualizations, the methods we used for this study and further the map themes classification. The general and technical requirements for the visualizations within the project "Risk Map Germany" are outlined in Sect. 3. An elaborative conclusion with focus on future developments in Sect. 4 closes this paper.

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1.2 GIS applications for the Internet

As Taylor (1994) predicted, new ways of cartographic visualization were explored and discovered in the last years due to the digital innovations. In this context Geographic Information Systems (GIS) play a leading role for the visualizing of spatial data. GIS are meanwhile a widely spread tool for the handling of all kind of geodata. Besides visualization, GIS are well known for storing, manipulating and analyzing of spatial data. Several years ago GIS were used as stand-alone applications and limiting the number of users who have access to a GIS software (Peng and Tsou, 2003). With the use of Web technology GIS concepts become more open, accessible and mobile (Dragicevic, 2004). A growing number of GIS software developers equip their software with online functionalities so that the Internet could become the general platform for the distribution of geo-information (Green und Bossomaier, 2002). Different terms have been used for the developments of GI-Systems for the World Wide Web: they called e.g. Distributed Geographic Information (DGI) (Plewe, 1997), Internet GIS (Peng, 1999), On-line-GIS or Web-based GIS. These terms differ sometimes also in their meaning, but in general they all deal with Web technologies. However, it seems the simple term Web-GIS has become widely accepted.

Web-GIS facilitate the open use of GIS to spatial data access and dissemination, to spatial data exploration and geovisualization and to spatial data processing and ergo it contributes to the democratization of spatial data (Dragicevic, 2004). Today Web-GIS are mostly not complete GI-Systems in contrast to Desktop-GIS which have a broad range of functionalities. There exist a great number of applications which focus on various aspects of Web-GIS. For example, Web-GIS applications span from Web mapping applications for the distribution of static maps like the PCL Map Collection of the University Texas (PCL, 2006), to Web-GIS products which include multimedia (Cartwright, 1999), to the realization of electronic atlases like the Internet atlas of Switzerland (Richard, 2000). Other kinds of Web-GIS applications are Mobile-GIS solutions that can be found in cellular phones or mobile navigators etc. These Web-GIS provide in most cases just few GIS-functionalities and therefore they can be regarded as pure information systems.

Distributed GIS is a network-centric approach of GIS which deliver geoinformation and analysis tools over the Internet. Data and processing tools can be integrated locally in a Web client like a standard Web browser and provide functionalities like a real Desktop GIS. Different type of data and analysis tools are allocated on different servers. Such distributed GIS uses the advantage of the Internet as a giant distributed system (Peng and Tsou, 2003). A distributed GIS consists of several open and interoperable components which can be requested by users to establish so called GI services. This enables a number of service possibilities like searching for geospatial data, spatial data sharing and on-line processing or location based services (LBS). In the disaster and risk management a few projects implementing a distributed GIS were realized. For instance, Latini and Köbben (2005) developed a landslide inventory tool which enables municipalities to sketch landslides without having a GI-System. Furthermore, a few projects are in progress, staying in a conceptual stage like a distributed spatial data library (Hunter, 2005) or a content based image search for satellite images (Göbel, 2005).

To enable these interoperable GI-Services the compliance of standards like the International Standardisation Organisation (ISO, 2003) and the Open Geospatial Consortium (OGC, 2002) specifications are compulsory conditions. These developments in software architecture enable users in an open distributed GIS service architecture to search, access and retrieve geodata and GIS analysis components from any server (Peng and Tsou, 2003). Current research efforts focus therefore on the interoperability of geoinformation. For example, the project ORCHESTRA, funded by the European Commission, will improve the interoperability in the multi-risk management by implementing open service oriented software architecture (Annoni et al., 2005).

Nevertheless, designed maps play an important role in a Web-GIS environment as well (Kraak, 2004). Atlases traditionally consist of a collection of maps which follow certain systematics, e.g. the same scale or the same theme. This definition also applies to a so-called electronic or digital atlas. In this work we use the term digital atlas as a synonym to Web-GIS.

Several applications of digital atlases which deal with the topics vulnerability, hazards and risks have already been implemented in the World Wide Web. For instance, there are some Web solutions containing hazard maps as a main component like the Multi-hazard Mapping Initiative by the Federal Emergency Management Agency (FEMA, 2005) in Washington D.C. or the interactive hazard atlas "CatNet" by the Swiss Re reinsurance company (SWISS RE, 2005). Another initiative is the "Coastal Risk Atlas" by the National Oceanic & Atmospheric Administration dealing with topics of vulnerability and risk (NOAA, 2005). A comprehensive elaboration of international initiatives on this topic is given by Maier (2005).

However, most of the currently available WWW solutions either focus on only one (natural) hazard or only on hazard or vulnerability/risk maps. In contrast, the "CEDIM Risk Explorer" combines three thematic map types, i.e. hazard, vulnerability and risk maps, for several hazards types in one application. In this context, the application was carried out as an interdisciplinary information platform. The challenge was among others to harmonize the heterogeneous data sets and the different results to common map visualization for Germany, for more details on harmonization see Köhler et al. (2006). At the end a comparative view of the different risks should be provided in the Web-GIS "CEDIM Risk Explorer".

Table 1. Data properties of hazard, vulnerability and risk maps in CEDIM and their suitable graphic compositions (Maier, 2005).

map/properties	Data characteristics						Suitable graphic compositions						
	discreta	continua	qualitative	quantitative	absolute	relative	graduated symbol map	choropleth/dasymetric map	filled-in isoline map	smooth statistical surface	stepped statistical surface	multivariate diagram map	small multiples
Hazard Map	—	✓	—	✓	✓	—	—	—	✓	✓	—	—	(✓)
Vulnerability Map	✓	—	—	✓	—	✓	✓	✓	—	—	✓	✓	✓
Risk Map	✓	—	—	✓	—	✓	✓	✓	—	—	✓	✓	✓

✓= yes, — = no, (✓) = partly suitable

2 Risk maps and cognate map compositions

2.1 Methods of visualization

The visualization of spatial data, especially according to cartographic standards, was a research subject for the last decades. The evolution of the communication-oriented cartographic research towards the recent map-based geovisualization has been pushed and accompanied by the Commission on Visualization and Virtual Environments of the International Cartographic Association (ICA) (see MacEachren and Kraak, 2001 or WWW: http://kartoweb.itc.nl/icavis/overview.html).

Declaring the aim, the purpose, and the use of the map is of crucial importance for a correct cartographic visualization. MacEachren and Kraak (1997, Fig. 2) defined four use goals in a map-use cube: exploring, analyzing, synthesizing and presenting. They conclude that the emphasis of one of them requires different visualization strategies. The map visualization in the "CEDIM Risk Explorer" meets the purposes of presentation and analysis (see Sect. 3). Thereby the presentation enables the cartographic communication between the map-user and the map. "Analysis" is here defined as a general search of new relationships between different data sources and the possibility to answer questions by maps, for example, the spatial analysis operation by the visual overlaying of two or more datasets and/or maps.

In order to meet the map goals in CEDIM and to visualize the statistical data within its spatial context in a suitable manner, the characteristics of the underlying phenomena have to be determined. A scientific classification of the represented phenomena helps to acquire knowledge about laws pertinent in single classes (Ogrissek, 1987). Efforts towards classification schemes in cartography were made e.g. by Imhof (1972) or Arnberger (1997). An enclosing compendium of the processing of spatial data including classification aspects is given by Andrienko and Andrienko (2005).

One important classification category relevant to the assignment of suitable graphic compositions for the map outcome of CEDIM is the *Data Characteristic*. Among others, it can be distinguished into the following classes: (1) *discreta*, (2) *continua*, (3) *qualitative*, (4) *quantitative*, (5) *absolute* and (6) *relative*. Having the knowledge on the classification category *Data Characteristics* in mind, suitable graphic compositions can be assigned as shown in Table 1.

A further methodological approach can be seen in the use of visual variables. The visual variables that fit best to represent areal phenomena at an ordinal or numerical measurement scale are lightness and hue (MacEachren, 1994; Slocum, 1999). By using hue to represent ordinal data, the cartographer has to maintain a carefully ordered selection, such as yellow, orange and red, which implies the ranked nature of the ordinal data. The map visualization in Fig. 1 of the Seismic Hazard Map of Germany gives an example for this method.

Another visual variable, described by Slocum (1999), is the variation of symbol sizes. Size can be applied in a proportional manner according to the data values to be visualized. Every symbol has a distinct size that can, in sum, overtax the perceptual skills for differentiation of a human observer. Hence, a similar method uses classification again to reduce the number of different symbol sizes to a perceptible degree. This method is referred as graduated symbols shown in Fig. 2. It provides a better overview of the data value distribution at a glance. However, the map in Fig. 2 shows the limitations of a paper printout at the chosen scale. The underlying information of community boundaries and settlement areas is almost entirely masked by the symbols. The symbols are also partly overlapping, especially in the dense middle part of map. This problem can be solved here by using a zoomable screen map representation, like the "CEDIM Risk Explorer", where a user can choose a customized scale that fits better to his requirements.

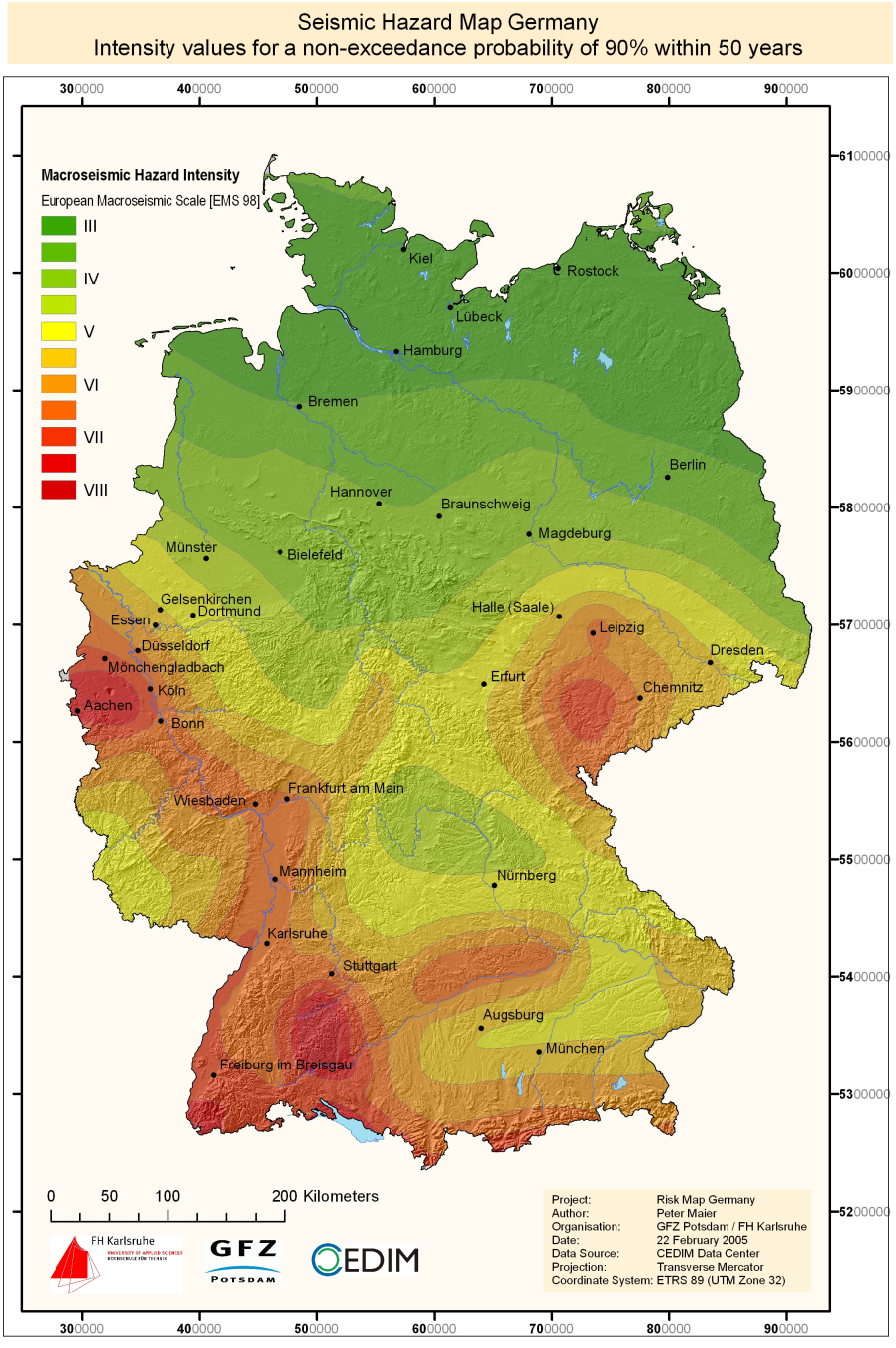

Fig. 1. Seismic Hazard Map Germany. Intensity values for a non-exceedance probability of 90% within 50 years. Example for a filled-in isoline map with steps in lightness and two hue transitions in the ordinal measurement scale (data source Tyagunov et al., 2006).

Finally, for the purpose of comparison of e.g. flood and storm or earthquake risks at the same location small multiples and diagram maps can be suitable. Small multiples refer to individual univariate maps that are displayed in a constant format and in ordered sequence next to each other. They fulfill the visualization tasks of (1) what is at a given location and (2) where is a given characteristic (Bertin, 1981, 1983). Small multiples are described by Tufte (2001) as the best solution for a wide range of problems in data representation. A diagram map enables users to directly compare quantitative values for a certain geographic location.

However, for the general map compilation in CEDIM it is important that quantitative data is classified and visualized using the same methodology that enhances the value comparability.

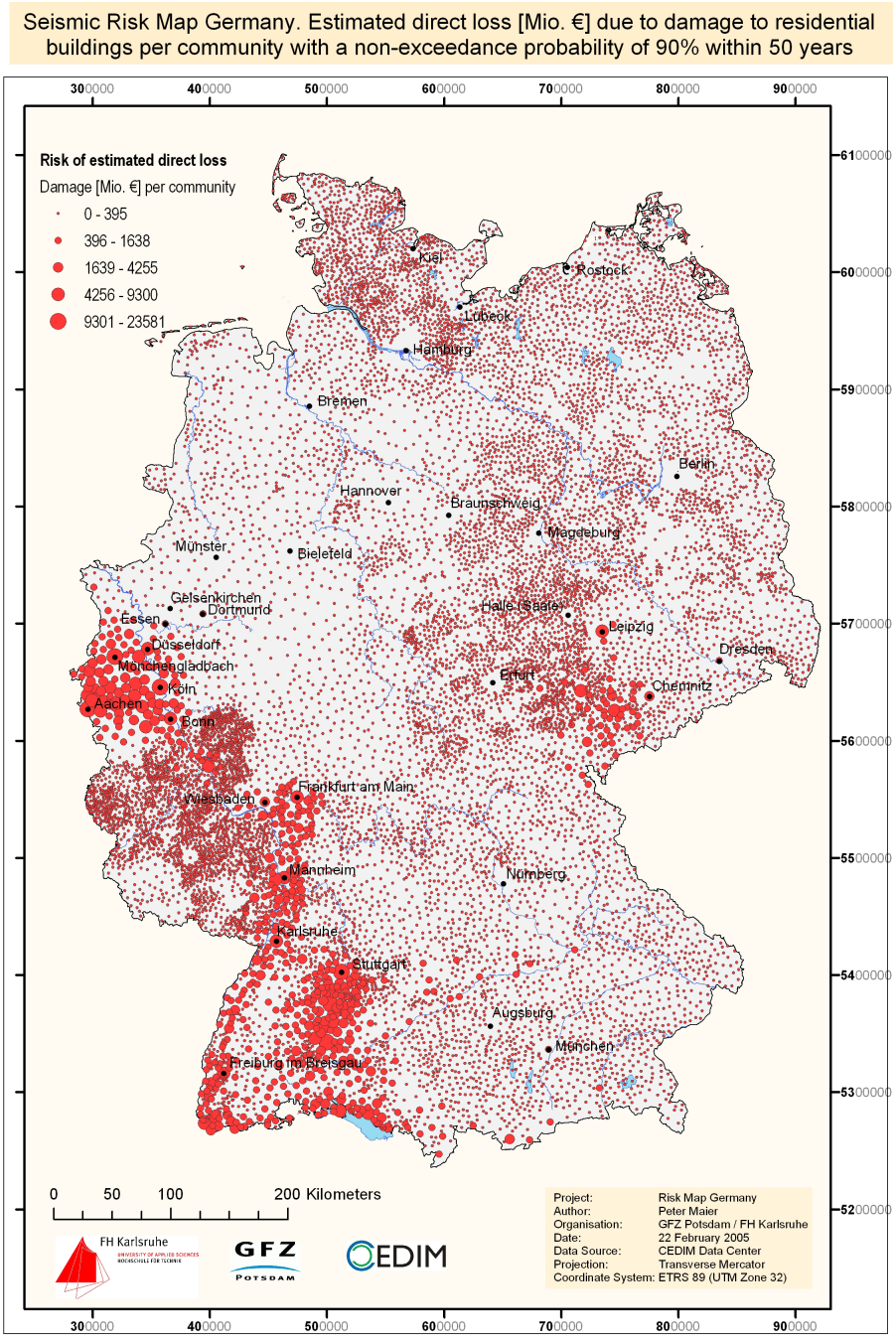

Fig. 2. Seismic Risk Map Germany. Estimated direct loss (Mio. EUR) due to damage to residential buildings per community with a non-exceedance probability of 90% within 50 years. Example for a graduated symbol map (Data source Kleist et al., 2006).

2.2 Map themes classification in the project CEDIM

Risk maps play an important role to visualize the results of a risk analysis. Risk assessment describes a methodology to analyse the intensities and probabilities of hazards in combination with the vulnerability of all the elements (objects, people etc.) in the region under study. Therefore, several steps of analysis and modelling have to be undertaken before a risk map is produced. Risk assessment shall be the first step in a serious consideration of disaster reduction strategies (United Nations ISDR, 2004). However, different approaches are possible like the three-stage procedure by Chung et al. (2005) where first a hazard prediction map is created, which is followed by a validation step and will finally end in the generation of a risk map.

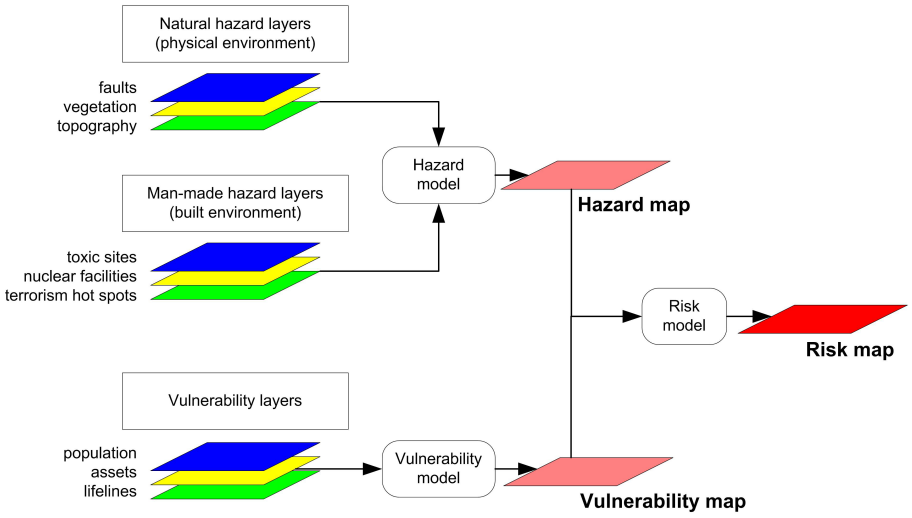

Fig. 3. Main map outcomes in CEDIM. Source: adapted from COVA (1999, Fig. 3).

Table 2. Overview about the preliminary map compositions.

	Hazard Map	Vulnerability Map	Risk Map
Earthquake Risk	1	1	1
Flood Risk	2	–	1
Storm Risk	4–5	2	4–5
Man Made Hazard	–	5	–
Asset Estimation	–	6	–

Within CEDIM risk is defined as the probability that a given loss will occur or will be exceeded. Based on this definition risk assessment is a three-stage procedure resulting in mainly three kinds of thematic maps schematically shown in Fig. 3: (1) hazard maps, (2) vulnerability maps and (3) risk maps (Cova, 1999). To distinguish between those three map representations the following definitions hold for CEDIM's Risk Map Germany project (Maier, 2005; Merz et al., 2005):

1. A Hazard Map, sometimes called Hazard Zonation Map, represents the spatial dissemination of a hazard and its intensity with the declaration of an assigned probability of occurrence or exceedance probability.

2. A Vulnerability Map is distinct for representations of the damage potential of a phenomenon (expressed in terms of relative or absolute monetary loss) on the one hand, and the susceptibility of elements at risk (accounts for parameters that affect the degree of destruction, e.g. building construction) on the other hand.

3. A Risk Map shows the spatial allocation of risk, which represents the expected damage or monetary loss and its assigned exceedance probability.

It has to be acknowledged that the definitions of vulnerability and risk used in the CEDIM project emphasize technical vulnerability and the assessment of direct economic damage and neglect many aspects of social vulnerability as they are discussed e.g. by Blaikie et al. (1994).

In the framework of a quantitative risk analysis, the determination of building assets and their spatial dissemination was an important step towards a common data set that has been used by different CEDIM research teams (e.g. flood, earthquake and storm) for risk analysis purposes. For a comparative risk analysis building assets were considered as elements at risk to be analyzed first (see Kleist et al., 2006 and Thieken et al., 2006). The cartographic outcome of the asset determination is assigned to the map classification "Vulnerability Map", since it is a step towards generation of vulnerability maps. The above mentioned map classifications of this study with the amount of the preliminary map realizations are shown in Table 2. This table represents first the map outputs of the earthquake risk of one map each for the three different map-kinds because earthquakes were just considered for the entire Germany without return periods. The other categories: Flood Risk, Storm Risk, Man Made Hazards and Asset Estimation will mostly results in more than one map. That is due to the investigated regions, e.g. on federal or community level and by the different hazard scenarios with various return periods. A few empty cells in Table 2 appear due to the nature of the investigated phenomena, e.g. the asset estimation can be only result in vulnerability maps which are then inputs for the generation of risk maps.

3 The "CEDIM Risk Explorer"

3.1 Requirements of the application

All Web-GIS are entirely or partly based on a map server technology, which was therefore also chosen for the implementation of the "CEDIM Risk Explorer". The digital atlas application named "CEDIM Risk Explorer" shall publish the risk information via the Internet in order to increase awareness to natural and anthropogenic risks. A range of potential users may comprise insurance and reinsurance companies, decision makers at various administrative levels (federal, regional, communal), emergency and catastrophic management or other researchers and interested public as well.

Several general requirements are imposed on the "CEDIM Risk Explorer" taking into account the range of potential users. For the users an operational availability must be given which is inherent by a Web application. The map information should reach the user in a sophisticated way so that an intuitive handling and map presentation are warranted. On the other hand, the underlying data must be protected from an unauthorized access. Finally, the conveyed information should give the current state of the research.

Furthermore, some graphical requirements should be fulfilled. For example, a well designed cartographic display can be easily understood by a wide audience (MacEachren and Kraak, 1997). A Web application, especially a cartographical visualization, has to warrant that a suitable graphic composition meets criteria for screen displays. These are e.g. a suitable line width, the possibility to adapt layer technique and the preference to visualize area symbols over line symbols. The Graphical User Interface (GUI) has particular relevance for the acceptance by the user. Graphical clearness and balance of the information volume and tools are therefore of enormous importance. The arrangement of the unique elements should be based on general design rules (Plewe, 1997). They define the central object, here the map view, in the middle with map navigation tools adhered to it. The user should be able to grasp the interface with one view.

3.2 Architecture, layout and functionality

The Web-GIS solution "CEDIM Risk Explorer" is structurally built as a typical Web client/server model. The architecture consists of a tier structure (Fig. 4). From a logically architecture view it is a so-called three-tier structure where the tiers are termed as *presentation*, *logic* and *data* (Peng and Tsou, 2003). This application is also shared in a physically two-tier structure on the other side. Thereby the *presentation tier* resides on the client side in a Web browser or a GIS-Software client and covers the visualization part. On the other hand, the *logic tier* and the *data tier* are located on a server side.

Figure 4 further indicates the data flow of the application based on the commercial software package ArcIMS (Internet

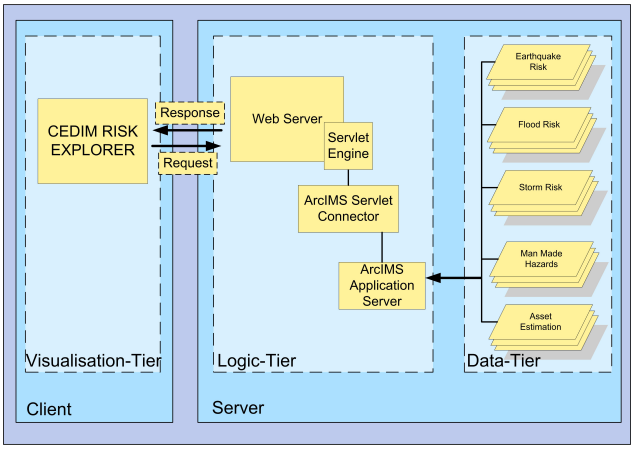

Fig. 4. Client/Server system of the "CEDIM Risk Explorer" in logically three-tier and physically two-tier architecture.

Map Service) by the Environmental System and Research Institute, Redlands CA. (ESRI). A user request is transmitted through the Web server further to the map server. The map server generates a raster image from the data tier which is visualized by an image service back through the Web browser.

In this study an existing map server application, the "CEDIM Data Center" could be used as a layout template. The "CEDIM Data Center" is an implemented map-server solution of the sub-project "Data management and GIS" inside CEDIM (Köhler et al., 2006). This application works as a Geodata-Server, which gives an overview of spatial data sets to the members of CEDIM and provides data download functionality (Köhler et al., 2004). The kernel of the "CEDIM Risk Explorer" is based on this Geodata-Server due to the expected high effectiveness and low realization costs.

The "CEDIM Risk Explorer" – in its layout shown in Fig. 5 – offers a structural customized table of contents based on the JavaScript dbGroupToc15a (Bollinger, 2004). The table of contents gives an overview of available map layers distinguished in hazard, vulnerability and risk maps, with each group containing the subgroups referring to a certain type of threat (storm, earthquake, flood and man made hazard). The group of vulnerability maps also includes general maps about number of people and assets potentially at risk as presented by Kleist et al. (2006) and Thieken et al. (2006). The table of contents provides the functionality of toggling the map layers. Together with a range of base maps and digital elevation models it gives potential users the possibility to compose different maps for their own needs. The user has thereby the possibilities to choose a custom geographical area and to combine the risk information layers for his/her needs. A print function provides additional generation of a custom map to the user. A print form in a fixed "CEDIM Risk Explorer" layout gives a print preview with additional information like a reference to the map data for the user-composed maps. The printout also includes an overview window indicating a

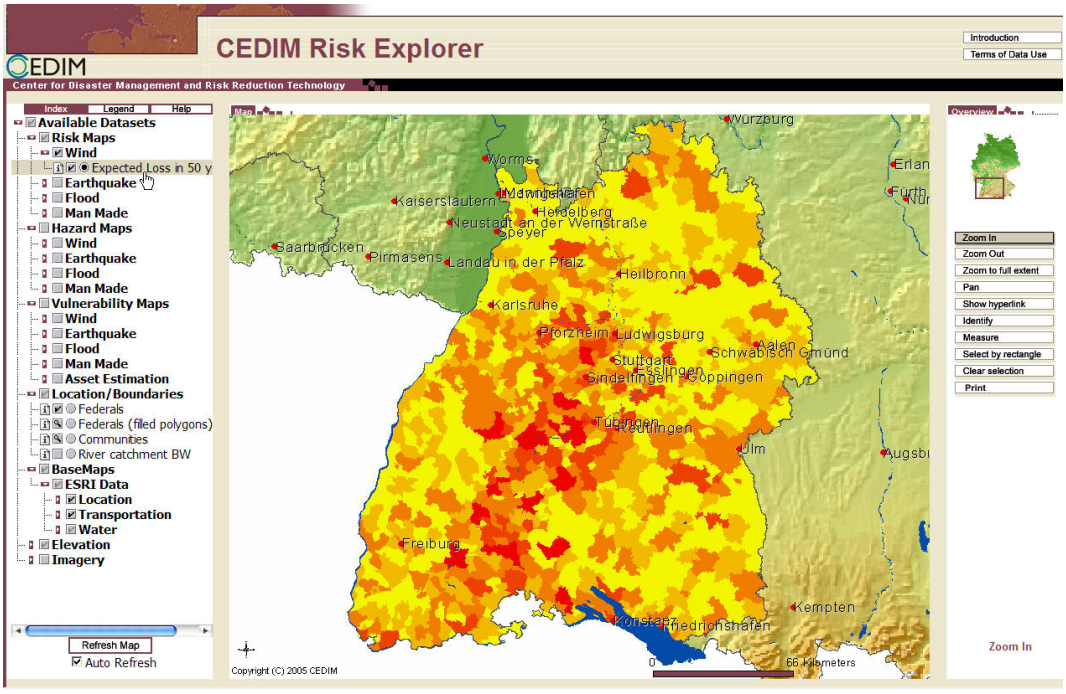

Fig. 5. Layout of the CEDIM Risk Explorer – table of contents, map window, toolbar.

localization of the selected printed map section on the whole map extent, and a legend of features selected for printing.

Metadata for each map layer can be accessed through the layer information icon in the Web-GIS contents. The metadata generation in CEDIM follows the international standard "ISO 19115: Geographic Information – Metadata" (ISO, 2003). Accordingly a CEDIM standardized and approved metadata profile was developed that allows the standardized documentation of the used data and generated maps (Köhler et al., 2006).

4 Conclusion and further development

With the "CEDIM Risk Explorer" a (preliminary) Web-GIS application was implemented to publish CEDIM research results as maps representing natural and man made hazards, vulnerabilities and risks. These thematic maps shall be available for the interested audience through a standard Web browser enabling the user to generate map compositions for their own needs. The "CEDIM Risk Explorer" gives a consistent overview of the CEDIM research project results. Users can compare different hazards and risks on specified locations in Germany. The consistent data and map base will serve as an important prerequisite for a multi-risk analysis, which is currently carried out. Due to the map presentations a better spatial understanding about the different threats can be transferred to the users. The easy comprehensibility and comparability of the map presentations emphasize the existing spatial relations to the user rather than the creation of new knowledge (MacEachren and Kraak, 1997).

During the study a successful map classification in hazard, vulnerability and risk categories was achieved. Thus, the implementation of an accurate cartographical visualization of the phenomena could be attained. Currently, choropleth maps, which show phenomena of area distribution, and graduated symbol maps, which show point phenomena, are used for the map representation in the "CEDIM Risk Explorer". Also dasymetric maps (see Thieken et al., 2006) were adopted for a better dissemination of spatial phenomena. The shown map compositions exemplify the current know-how of risk mapping adopted in CEDIM.

The technical improvement and the overcoming of the prototype status of this Web-GIS is a challenge for future activities. The current "CEDIM Risk Explorer" application represents a prototype which demands further development. The initial maps of vulnerability, hazard and risk are predefined by the interdisciplinary researchers. Thus, the users have limited interactive and explorative operations to generate new maps. It would be more sophisticated if the users could choose the color or the class range of the maps themselves. Consequently, a better interactive manipulation (Andrienko and Andrienko, 1999) provided for the users is desirable for the map compositions. Another challenge is the increasing amount of data and maps, leading to slower performance. The implementation of a suitable geo-database into the existing map server architecture will provide better performance as well as a dynamic map generation from updated data and the promotion of a certain data consistency.

All the desired improvements lead to an ongoing development of the "CEDIM Risk Explorer" to a real open and interoperable distributed GIS as mentioned in Sect. 1.2 and the deployment as a GIS Web Service in the next future. Since the comparability of hazards and risks is one of the main characteristics of the "CEDIM Risk Explorer", however the use of a distributed environment could lead to data misinterpretations. It is normally unknown, with which method the map contents of the remote data sources were visualized. For instance this could have happened for the used classification method of data in the certain class-ranges or class-breaks. Different variations of a classification arise therefore in various map views and could promote fail interpretations (Monmonier, 1991). However, a general recipe for a correct classification could not be found (Andrienko and Andrienko, 2005). Therefore, careful use of the data visualization in regard to the value comparability should be present.

Nevertheless interoperable Web-GIS for the "CEDIM Risk Explorer" shall be soon achieved so that the current solution can be regarded as an intermediate step on the way to a GIS Web service which operates as a GIS node in an open GIS network in future.

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References

Andrienko, G. and Andrienko, N.: Interactive Maps for Visual Data Exploration, Int. J. Geograph. Inf. Sci., 13, 355–374, 1999.

Andrienko, N. and Andrienko, G.: Exploratory Analysis of Spatial and Temporal Data: A Systematic Approach, Berlin Heidelberg, Springer, XV, 703 p., 2005.

Annoni, A., Bernhard, L., Douglas, J., Greenwood, J., Laiz, I., Lloyd, M., Sabeur, Z., Sassen, A.-M., Serrano, J.-J., and Usländer, T.: Orchestra: Developing a Unified Open Architecture for Risk Management, in: Geo-information for Disaster Management, edited by: v. Oosterom, P., Zlatanova, S., and Fendel, E. M., Berlin Heidelberg, Springer, 1–17, 2005.

Arnberger, E.: Thematische Kartographie. Mit einer Kurzeinführung über EDV-unterstützte Kartographie und Quellen der Fernerkundung: Das geographische Seminar, Braunschweig, Westermann Schulbuchverlag GmbH, 1–245 ,1997.

Bertin, J.: Graphics and Graphic Information-Processing, Berlin, New York, Walter de Gruyter, 1–274, 1981.

Bertin, J.: Semiology of Graphics: Diagrams, Networks, Maps, Madison, WI, University of Wisconsin Press, 1983.

Blaikie, P., Cannon, T., Davis, I., and Wisner, B.: At risk. Natural hazards, people's vulnerability, and disasters, Routledge, London, New York, 1994.

Bollinger, D.: dbGroupToc15a ArcScript, electronic source: http://arcscripts.esri.com/details.asp?dbid=12191, accessed Jan. 2004, Redlands, USA, ESRI Support Center, 2003.

Cartwright, W., Peterson, M. P., and Gartner, G.: Multimedia cartography, Berlin Heidelberg, Springer, 361 p., 1999.

Chung, C.-J. F., Fabbri, A. G., Jang, D.-H., and Scholten, H. J.: Risk Assessment Using Spatial Prediction Model for Natural Disaster Preparedness, in: Geo-information for Disaster Management, edited by: v. Oosterom, P., Zlatanova, S., and Fendel, E. M., Berlin Heidelberg, Springer, 619–640, 2005.

Cova, T. J.: GIS in Emergency Management, in Geographical Information Systems: Management Issues and Applications, edited by: Longley, P. A., Goodchild, M. F. Maguire, D. J., and Rhind, D., New York, John Wiley & Sons, Inc., 2, 845–858, 1999.

Dragicevic, S.: The potential of web-based GIS, J. Geograph. Syst., 6, 79–81, 2004.

Federal Emergency Management Agency (FEMA), electronic source: http://www.fema.gov/hazard/index.shtm, accessed October 2005, Washington D.C., USA, FEMA, 2005.

Göbel, R., Almer, A., Blaschke, T., Lemoine, G., and Wimmer, A.: Towards an Integrated Concept for Geographical Information Systems in Disaster Management, in: Geo-information for Disaster Management, edited by: v. Oosterom, P., Zlatanova, S., and Fendel, E. M., Berlin Heidelberg, Springer, 715–732, 2005.

Green, D. and Bossomaier, T.: Online GIS and Spatial Metadata, London – New York, Taylor & Francis Inc., 2002.

Hunter, T.: A Distributed Spatial Data Library for Emergency Management, in: Geo-information for Disaster Management, edited by: v. Oosterom, P., Zlatanova, S., and Fendel, E. M., Berlin Heidelberg, Springer, 733–750, 2005.

Imhof, E.: Thematische Kartographie, Berlin, Walter de Gruyter & Co., 360 p., 1972.

International Standard Organization (ISO): International Standard ISO 19119, Geographic Information – Services, ISO/TC 211, 2003.

International Standard Organization (ISO): International Standard ISO/DIS 19115 (ISO/TC211), Geographic information – Metadata, electronic source: http://www.iso.org/iso/en/CatalogueDetailPage.CatalogueDetail?CSNUMBER=26020{\&}ICS1=35{\&}ICS2=240{\&}ICS3=70, accessed October 2005, Genf, International Standardization for Organization, 2003.

Kleist, L., Thieken, A. H., Köhler, P., Seifert, I., Borst, D., and WERNER, U.: Estimation of Building Values as a Basis for Comparative Risk Assessments, Nat. Hazards Earth Syst. Sci., 6, 541–552, 2006, http://www.nat-hazards-earth-syst-sci.net/6/541/2006/.

Köhler, P., Müller, M., and Sanders, M.: Daten- und Informationsmanagement im Center for Disaster Management and Risk Reduction Technology (CEDIM), in: Angewandte Geoinformatik 2004, Beiträge zum 16. AGIT-Symposium Salzburg, edited by: Strobl, Blaschke, Griesebner, Salzburg, Herbert Wichmann Verlag, 359–364, 2004.

Köhler, P., Müller, M., and Sanders, M., and Wächter, J.: Data Management and GIS in the Center for Disaster Management and Risk Reduction Technology (CEDIM): From integrated spatial data to the mapping of risk, Nat. Hazards Earth Syst. Sci., 6, 621–628, 2006, http://www.nat-hazards-earth-syst-sci.net/6/621/2006/.

Kraak, M. J.: The role of the map in a Web-GIS environment, J. Geograph. Syst., 6, 83–93, 2004.

Latini, M. and Köbben, B.: A Web Application for Landslide Inventory Using Data-Driven SVG, in: Geo-information for Disaster Management, edited by: v. Oosterom, P., Zlatanova, S., and Fendel, E. M., Berlin Heidelberg, Springer, 1041–1054, 2005.

MacEachren, A. M.: Some Truth with Maps: A Primer on Symbolization and Design, Resource Publications in Geography, v. IV: Washington, D.C., Association of American Geographers, 1–129, 1994.

MacEachren, A. M. and Kraak, M. J.: Research Challenges in Geovisualization, Cartography and Geographic Information Science, 28(1), 3–12, 2001.

MacEachren, A. M. and Kraak, M. J.: Exploratory cartographic visualization: Advancing the agenda, Computers & Geosciences, Exploratory Cartographic Visualisation, 23, 335–343, 1997.

Maier, P.: Development of a Risk Mapping Concept for CEDIM Based on an Investigation and Evaluation of Cartographic Methods Used for Mapping Hazard, Vulnerability and Risk, Master Thesis, University of Karlsruhe, Karlsruhe – Potsdam, 1–87, 2005.

Merz, B., Thieken, A. H., and Gocht, M.: Flood risk mapping at the local scale: Concepts and challenges, in: Flood Risk Management in Europe: Innovation in Policy and Practice, edited by: Begum, S., Hall, J., and Stive, M., Dordrecht, Kluwer Academic Publishers, 2005.

Monmonier, M.: How to lie with Maps, Chicago London, University of Chicago Press, 176 p., 1991.

NOAA & NCDDC: National Oceanic and Atmospheric Administration & Coastal Data Development Centre, electronic source: http://www.ncddc.noaa.gov/cra, accessed October 2005.

OGC: The OpenGIS Abstract Specification, Topic 12: OpenGIS Service Architecture, Version 4.3., 2002, electronic source: http://www.opengeospatial.org/specs/?page=abstract, accessed October 2005.

OGC: Web Map Service Implementation Specification, 2006, electronic source: http://www.opengeospatial.org/specs/?page=specs, accessed April 2006.

Ogrissek, R.: Theoretische Kartographie, Studienbücherei Kartographie, v. Band 1: Gotha, VEB Hermann Haack, 257–261, 1987.

PCL: Perry Castaneda Library – Map Collection. Austin, University of Texas, electronic source: http://www.lib.utexas.edu/maps/asia.html, accessed February 2006.

Peng, Z.-R.: An assessment framework for the development of Internet GIS, Environment and Planning B: Planning and Design, 29, 117–132, 1999.

Peng, Z.-R. and Tsou, M.-H.: Internet GIS: Distributed Geographic Information Services for the Internet and Wireless Networks, Hoboken, New Jersey, John Wiley & Sons, Inc., 720 p., 2003.

Plewe, B.: GIS Online: information retrieval, mapping, and the Internet, SantaFe, Onword Press, 1997.

Richard, D.: Development of an internet atlas of Switzerland, Computers & Geosciences, 26, 45–50, 2000.

Slocum, T. A.: Thematic Cartography and Visualization, New Jersey, Prentice Hall Inc., 1999.

Swiss Re: CatNet, electronic source: https://entry.swissre.com/webapp/sls/frameset.jsp?requestedPage=/webapp/c4c/, accessed October 2005, Zurich, Swiss, 2005.

Taylor, D. R. F.: Cartographic Visualization and Spatial Data Handling, in: Advances in GIS research, Proceedings of the 6th international symposium on spatial data handling, edited by: Waugh, T. C. and Healey, R. G., Edinburgh, August 1994, two volumes, Vol. 1, London, Taylor & Francis, 1140 p., 1994.

Thieken, A. H., Müller, M., Kleist, L., Seifert, I., Borst, D., and Werner, U.: Regionalisation of asset values for risk analyses, Nat. Hazards Earth Syst. Sci., 6, 167–178, 2006, http://www.nat-hazards-earth-syst-sci.net/6/167/2006/.

Tufte, E. R.: Envisioning Information, Graphics Press, 126 p., 2001.

Tyagunov, S., Grünthal, G., Wahlström, R., Pohl, D., Stempniewski, L., and Zschau, J.: Seismic Risk Mapping for Germany, Nat. Hazards Earth Syst. Sci., 6, 573–586, 2006, http://www.nat-hazards-earth-syst-sci.net/6/573/2006/.

United Nations ISDR: Living with Risk: A global review of disaster reduction initiatives, Geneva, Switzerland, Inter-Agency Secretariat of the International Strategy for Disaster Reduction (UN/ISDR), 430 p., 2004.