SPATIAL DATA INFRASTRUCTURES FOR EMERGENCY SERVICES AND SECURITY MANAGEMENT

R. BILL
Prof. Dr.-Ing Ralf Bill, Chair of Geodesy and Geoinformatics, Faculty of Agricultural and Environmental Sciences, Rostock University, D-18051 Rostock, e-mail: ralf.bill@uni-rostock.de

Abstract: Spatial information plays a major role in case of an emergency or when taking security measures. Emergency services need information of high relevance, quality and timeliness to prepare decisions and to control the assignment of people and equipment in case of emergencies. In most countries of the world spatial data infrastructures (SDI) are under development. This paper will review the current situation of information availability and exchange in emergency and disaster cases and will identify the existing problems for integration of information. SDIs are focusing on this critical process of efficient integration of information. Thus, they may be powerful tools to improve information access and availability in emergency scenarios.

Keywords: spatial data infrastructure, web services, Open Geospatial Consortium, ISO, emergency services, security management

1. Motivation

Security is accepted to be one of the basic needs in a society. Recent events such as the New York terrorist attacks in September 2001, the Elbe flooding in August 2002 and the Indonesia Tsunami in December 2004 show clearly that society has to be prepared to deal with different types of risks and hazards.

Within the European Union the common European Security doctrine from 2003 defined five major hazards:

H. Gonca Coskun et al. (eds.), Integration of Information for Environmental Security, 233–245.

- Terrorism
- Further dissemination of weapons of mass destruction
- Regional conflicts
- Collapse of nations
- Organized crime

Additionally, certain types of natural risks have to be taken into account such as earthquakes and flooding.

The market volume for private security-relevant technologies and services worldwide is estimated to be around US$120 billion with annual growth rates of around 7–8%. Thus, political decision makers on all levels are discussing and providing regulations and laws for the different emergency cases.

2. Importance of Spatial Information

Spatial information plays a major role in case of an emergency or when taking security measures. In most of the developed countries spatial information exists, even in digital form in a more or less acceptable quality. Nevertheless, the information is often hidden, is not retrievable, perhaps because of data protection laws, does not fulfill current standards for information exchange or is not ready to use. Especially in cases where immediate decisions have to be taken, this situation concerning information availability and dissemination is not acceptable. Recent developments in spatial information systems and sciences may help to overcome such problems.

Emergency services such as fire brigades, ambulances, police forces, disaster control units, the military, primary control units for emergency and security services, technical assistance organizations, aid organizations and sentries need information of high relevance, quality and timeliness to prepare decisions and to control the assignment of people and equipment in case of emergencies. One part of this information, possibly even the most important part, is related to space, because all of the emergency cases happen somewhere on local, regional, national and even international level (i.e., across borders, reference systems and organization structures established in individual countries).

The spatial information is needed in at least three different phases of any emergency case (Strobl, Roth, 2006):

- Proactive – Before an event spatial information is necessary to create awareness and preparedness amongst citizens and emergency organizations. Awareness includes the preparation for potential events, warning of concrete risks, prevention and risk provision, damage management before an event, risk estimation, damage potential analysis, simulation exercises, crisis operation plans, planning scenarios, prognosis and protection tasks.

- Reactive – During an event one has to cope, control and manage emergency units. For the protection of people and infrastructure spatial information is needed. Damages have to be minimized and repaired.
- Postactive – After an event the reconstruction and risk management has to be done. Analysis and evaluation of the damages and the restoration and reconstruction of the infrastructure are the most important tasks here.

Many stakeholders must be involved in the processes; these are, e.g., emergency services, administrative organizations, politicians, mass media, planning organizations, enterprises, insurance companies and citizens (Figure 1).

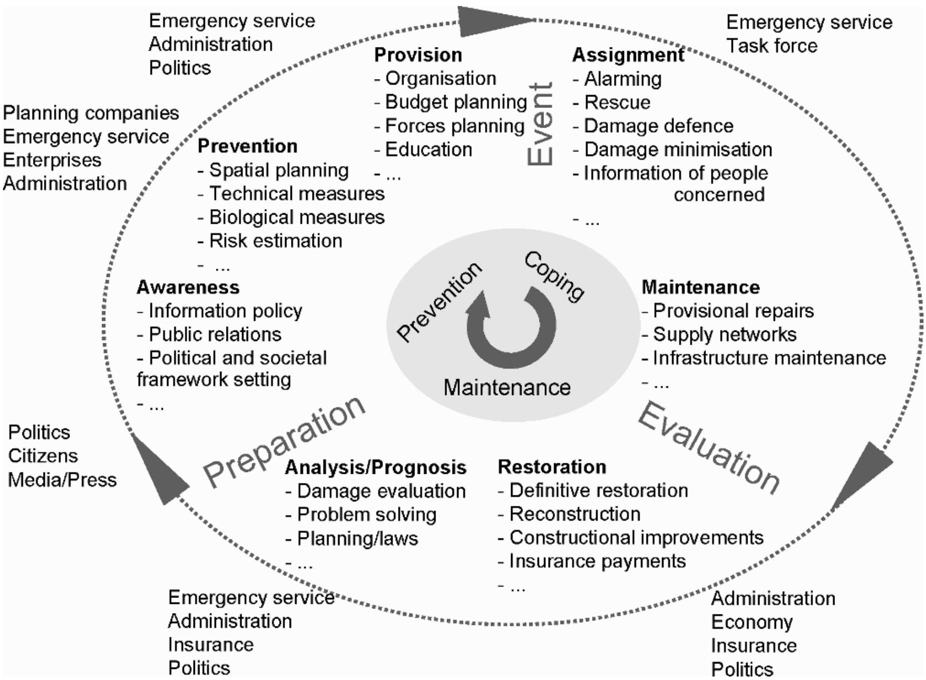

Figure 1. Phases and recipients in emergency cases and security management.

3. Components During Operations

The primary control unit is usually the backbone of any emergency service, e.g., in a police or fire brigade. It supports schedulers in the control unit for managing the progress of operations: from registration of the event and alerting the personnel to documentation of the development of an operation. GIS in many cases is simply an optional software tool, for instance, for navigating the service units to the event or for site visualization using maps. Further stationary components may be emergency information and management systems, information systems on dangerous goods, chemical or biological databases, knowledge databases, literature databases, addresses and link collections.

Alarm and warning systems are further components. In Germany, the deNIS (deutsches Notfallvorsorge-Informations system – German emergency preparedness information system) is under development including a variety of information such as online weather warning or risk sites in Germany (www.denis.bund.de/). deNIS informs about types of danger, possibilities to protect against hazards as well as on potential for personnel and material assistance in Germany.

The OASIS project (www.oasis-fp6.org), cofunded by the European Commission, addresses the strategic objective, "Improving Risk Management", of the second call for tender of the European Commission FP6 Information Society Technologies programme. The goal is to develop a disaster and emergency management system aiming to support the response operations in the case of large-scale as well as local emergencies subsequent to any kind of disaster. This should be usable at different levels of the civil protection organizations, European, national, regional or local, and facilitate the cooperation between the information systems used by the organizations.

As well as stationary components, mobile components such as navigation systems supporting the determination and following of a shortest path to the site of operation play an important role. Mobile operation systems may be used in the field as an onboard computer (e.g., a laptop in the car) or mobile during operation (PDA, tablet PC and cell phone). The fire brigade at Munich University, for instance, is investigating a mobile tablet PC-based information system during operation (TUM, 2005).

The current situation in emergency services and security management may be characterized as follows (without any assumption of completeness):

- Processes and data are under various responsibilities, an integrated workflow orientation crossing organization borders does not exist.
- Different hardware and software platforms may be found, often stand-alone and/or incompatible with each other and not supporting data exchange and common usage of data.
- Typical products needed for emergency services and security management exist in analogue form such as city and location maps, evacuation plans, stand-by call lists, operator handbooks, laws, regulations, task descriptions, literature collections. Databases, dangerous good information files, maps/

spatial information, feature information, substance databases, mobile routing of cars and persons may be available in digital form.

- A change from analogue media (paper maps, lists, etc.) to a digital form may be planned or underway. Nevertheless, this often results in a lot of unstructured links and pdfs, file cards, address collections, etc.
- In most cases metainformation does not exist or is not collected in a structured manner which makes it very complicated to embed the digital information in integrated workflows between different responsible parties.
- An integrated data fusion and data analysis is not supported.

Figure 2 illustrates the different components and defines the need for a technological approach to solve some or many of the mentioned problems. The technological solution integrates information systems and communication systems using Internet technologies. A major component is the spatial data infrastructure (SDI).

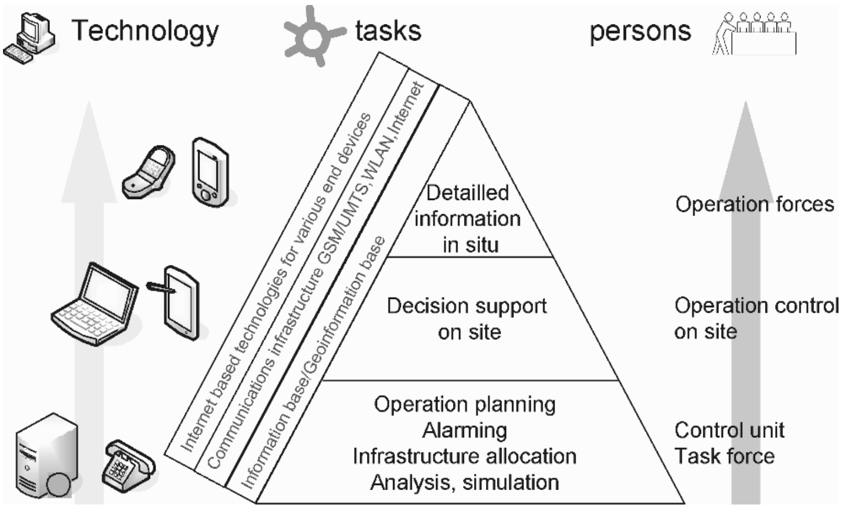

Figure 2. Components and technological approach.

4. Spatial Data Infrastructures

4.1. DEFINITION

A spatial data infrastructure (SDI) is a base collection of technologies, policies and institutional arrangements that facilitate the availability of and access to spatial data. The SDI provides a basis for spatial data discovery, evaluation and application for users and providers within all levels of government, the commercial sector, the nonprofit sector, academia and by citizens in general (Nebert, 2001). In an SDI, providers of geodata services and users of such services are somehow cooperating. Thus, an SDI is a prerequisite to create added-value services for many users in administration as well as in commercial and noncommercial fields.

4.2. IMPLEMENTATION

In most countries of the world spatial data infrastructures, so-called National Spatial Data Infrastructures (NSDI), are under development, for instance, GDI.DE in Germany. Even on a global (e.g., GSDI, ESDI-/INSPIRE in Europe) and regional (e.g., GDI.NRW) or municipality level the setup of SDIs is in progress. They consist of technical, organizational and legal components, including spatial information resources (geoinformation, metainformation and geoservices) and allow users to interact based on common standards without hindrances (Figure 3).

Level	Content
Organisational level	Target orientated linkage of administration, enterprises, science and citizens under feasible frame conditions
Legal level	Definition of access- and usage conditions, price models etc., SDI-guidelines integrated in the statutes of organisations and administrative units/disciplines
Data level	Integration and setup of transparent offers, standardising data/meta data
Technology level	Application of standardised architectures/interfaces, interoperability of heterogeneous applications

Figure 3. Levels of spatial data infrastructures.

The dissemination of the spatial information is based on web services in the Internet. Standards for the spatial information description are defined and published by ISO (International Organization for Standardization). Abstract and implementation specifications are established by the Open Geospatial

Consortium (OGC) and implemented in many GIS products on the market. Since 1997, ISO and OGC are working closely together in TOCG (TC211–OGC coordination group). The major outcomes of these processes are described in the following sections.

4.3. STANDARDS

4.3.1. *International Organization for Standardization*

ISO is the union of the national standardization institutions. Since November 1994, a technical committee (TC 211, see http://www.isotc211.org/, another one is TC 204 dealing with car navigation) has been developing standards in the field of digital geographic information. This work aims to establish a structured set of standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth. These standards may specify, for geographic information, methods, tools and services for data management (including definition and description), acquiring, processing, analyzing, accessing, presenting and transferring such data in digital/electronic form between different users, systems and locations. The work shall link to appropriate standards for information technology and data where possible, and provide a framework for the development of sector-specific applications using geographic data. The overall objectives of ISO/TC 211 are:

- To increase the understanding and usage of geographic information
- To increase the availability, access, integration and sharing of geographic information
- To promote the efficient, effective and economic use of digital geographic information and associated hardware and software systems
- To contribute to a unified approach to addressing global ecological and humanitarian problems (http://www.isotc211.org/)

TC 211 has around 29 participating members and 31 observing member countries and many external liaisons with working groups and project teams from scientific and other communities. Four (of five) working groups are active at the moment:

- Working group 4 Geospatial services
- Working group 6 Imagery
- Working group 7 Information communities
- Working group 8 Location-based services (suspended)
- Working group 9 Information management

ISO TC 211 has defined and published the following standards in the ISO 191xx series (recent list from http://www.isotc211.org). For further details see Kresse and Fadaie (2004).

ISO 6709:1983 Standard representation of latitude, longitude and altitude for geographic point locations
ISO 19101:2002 Geographic information – Reference model
ISO/TS 19103:2005 Geographic information – Conceptual schema language
ISO 19105:2000 Geographic information – Conformance and testing
ISO 19106:2004 Geographic information – Profiles
ISO 19107:2003 Geographic information – Spatial schema
ISO 19108:2002 Geographic information – Temporal schema (*Cor 1*:2006)
ISO 19109:2005 Geographic information – Rules for application schema
ISO 19110:2005 Geographic information – Methodology for feature cataloguing
ISO 19111:2003 Geographic information – Spatial referencing by coordinates
ISO 19112:2003 Geographic information – Spatial referencing by geographic identifiers
ISO 19113:2002 Geographic information – Quality principles
ISO 19114:2003 Geographic information – Quality evaluation procedures (*Cor 1*:2005)
ISO 19115:2003 Geographic information – Metadata (*Cor 1*:2006)
ISO 19116:2004 Geographic information – Positioning services
ISO 19117:2005 Geographic information – Portrayal
ISO 19118:2005 Geographic information – Encoding
ISO 19119:2005 Geographic information – Services
ISO/TR 19120:2001 Geographic information – Functional standards
ISO/TR 19121:2000 Geographic information – Imagery and gridded data
ISO/TR 19122:2004 Geographic information/Geomatics – Qualification and certification of personnel
ISO 19123:2005 Geographic information – Schema for coverage geometry and functions
ISO 19125-1:2004 Geographic information – Simple feature access – Part 1: Common architecture
ISO 19125-2:2004 Geographic information – Simple feature access – Part 2: SQL option
ISO/TS 19127:2005 Geographic information – Geodetic codes and parameters
ISO 19128:2005 Geographic information – Web map server interface
ISO 19133:2005 Geographic information – Location-based services – Tracking and navigation
ISO 19135:2005 Geographic information – Procedures for item registration

4.3.2. *Open Geospatial Consortium*

"The Open Geospatial Consortium, Inc. (OGC) is a nonprofit, international, voluntary consensus standards organization that is leading the development of standards for geospatial and location based services." (http://www.opengeospatial.org/). OGC was founded in 1994, originally named Open GIS Consortium. OGC integrates 333 members (GIS-vendors, service providers, IT- and DB-enterprises, data suppliers, universities and others). Different grades of membership reflect the influence in the standardization process and the financial engagement in OGC: strategic membership, principal plus membership, principal membership, technical committee membership and six types of associate membership.

The main goal is interoperability, i.e., "definition of a technology, which allows application developers and users to use all kind of geocoded data and geofunctionality or geoprocess being available in the net inside his own environment and individual workflows" (Open GIS Guide). Since 1999 the OGC has had a strong focus on Internet-based solutions.

Open GIS Specifications are the main "products" of the OGC. These are technical documents that detail interfaces or encodings, which software developers may use to build support for the interfaces or encodings into their products and services. These specifications address specific interoperability challenges. Ideally, when specifications are implemented by two different software engineers working independently, the resulting components plug and play, that is they work together without further debugging. The documents are available at no cost to everyone. The "Abstract Specification" provides the conceptual foundation for most OGC specification development activities. Open interfaces and protocols are built and referenced against the Abstract Specification, thus enabling interoperability between different brands and different kinds of spatial processing systems. At the present time OGC has defined more than 15 abstract specifications. The Abstract Specification provides a reference model for the development of Open GIS Implementation Specifications. "Implementation Specifications" are different from the Abstract Specification. They are written for a more technical audience and detail the interface structure between software components. An interface specification is considered to be at the implementation level of detail if, when implemented by two different software engineers in ignorance of each other, the resulting components plug and play with each other at that interface.

Current implementation specifications (version numbers in brackets) exist on (see http://www.opengeospatial.org/):

- *Web Map Service* (WMS 1.3.0) – creation and display of registered and superimposed map-like views of information as raster maps/imagery
- *Web Feature Service* (WFS 1.1.0) – to retrieve and update geospatial data encoded in vector form, typically as Geography Markup Language (GML), from multiple Web Feature Services
- *Web Coverage Service* (WCS 1.0.0) – extends the Web Map Service (WMS) interface to allow access to geospatial coverages (raster datasets) that represent values or properties of geographic locations
- *Catalogue Service Implementation Specification* (CSW 2.0.1) – defines a common interface that enables diverse but conformant applications to perform discovery, browse and query operations against distributed heterogeneous catalogue servers
- *Coordinate Transformation Service Implementation Specification* (1.0) – provides interfaces for general positioning, coordinate systems and coordinate transformations
- *Filter Encoding Implementation Specification* (FE 1.1) – defines an XML encoding for filter expressions
- *Geographic Objects Implementation Specification* (GO 1.0.0) – defines an open set of common, lightweight, language-independent abstractions for describing, managing, rendering and manipulating geometric and geographic objects within an application programming environment
- *Geography Markup Language* (GML 3.1) – is an XML encoding for the transport and storage of geographic information, including both the spatial and nonspatial properties of geographic features
- *Grid Coverage Service Implementation Specif*ication (1.0) – defines methods that allow interoperability between software implementations by data vendors and software vendors providing grid (raster) analysis and processing capabilities
- *Location Service (Open LS) Implementation Specification* (1.1) – is an open platform for location-based application services
- *Simple Features Implementation Specifications 1 and 2* (1.1.0), *CORBA* (1.0) and *OLE/COM* (1.1) – define interfaces that enable transparent access to geographic data held in heterogeneous processing systems on distributed computing platforms
- *Styled Layer Descriptor Implementation Specification* (SLD 1.0) – is an encoding that extends the Web Map Service specification to allow user-defined symbolization of feature data. It allows users (or other systems) to

determine which features or layers are rendered with which colors or symbols

- *Web Map Context Implementation Specification* (WMC 1.1) – a companion to the Open GIS Web Map Service describing how to save a map view comprised of many different layers from different Web Map Servers. A "context" can be encoded and saved so that Web maps created by users can be automatically reconstructed and augmented by the authoring user or other users in the future
- *Web Service Common Implementation Specification* (1.0) – details many of the aspects that are, or will be, common to all OGC Web Service interface Implementation Specifications

All together they define the base for a distributed, heterogeneous GI architecture. Almost all vendors of GIS products produce software based on one or more of these standards.

4.3.3. *Others*

Beside ISO and OGC there are other organizations defining the most common standards, i.e., the World Wide Web Consortium (W3C) with XML (Extensible Markup Language), DTD (Document Type Definition), XSL (Extensible Stylesheet Language) and SVG (Scalable Vector Graphics). Others are the Object Management Group (OMG) and IEEE.

5. Spatial Data Infrastructures for Emergency Services: Status and Research Demands

Figure 4 illustrates an example of an interdisciplinary spatial data infrastructure based on these standards and specifications, where different services are called from different clients through a portal and can be combined with each other.

5.1. CURRENT ACTIVITIES

At the moment there are many activities ongoing to improve the information situation in emergency services. Meta information is being created for data and services. Spatial data availability and dissemination is improving using interoperable interfaces, e.g., for base maps (real estate, topography, weather, traffic, pollutants, etc.). Guidance data (i.e., operation plans, operation forces, on-site info, history, documentation, static and situation based, etc.) are prepared in digital form. The integration of GIS data – describing outdoor environments – with facility management data (FM) – giving access to indoor information – using similar technologies is needed. Interoperability across different service units and near real-time delivery of information for task forces on-site is one of the major challenges today.

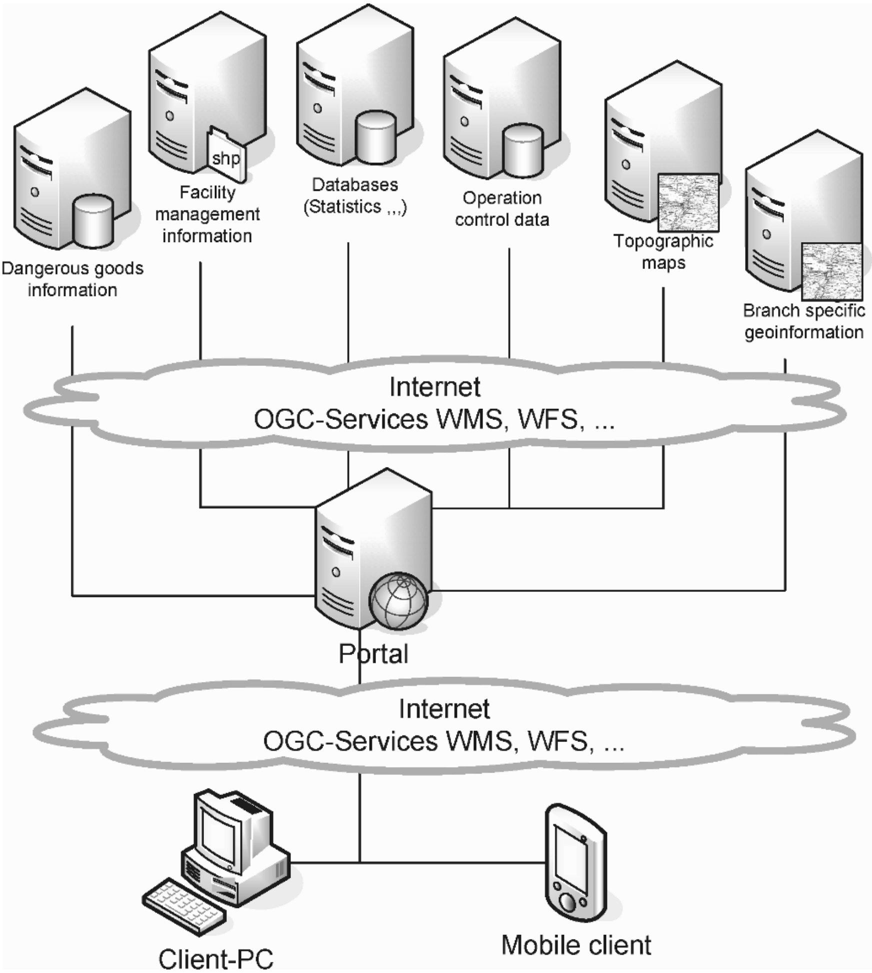

Figure 4. SDI architecture.

5.2. RESEARCH TOPICS

In future there are further activities needed. For early detection of natural danger and terrorist threats, mobile sensor networks (geosensor networks) have to be distributed to monitor, inspect, and supervise critical infrastructures. The support of the coordinated command of various operation forces using an interoperable GIS-based operation control unit has to be set up. Near real-time positioning, alerting and specific evacuation of population under threat is also a major issue. Besides the technological components further research is needed. These research issues are embedded in the current research topics such as ontologies, the semantic web, real-time sensors and real-time decisions based on decision support systems as well as ubiquitous computing.

References

Nebert, D., 2001, Developing Spatial Data Infrastructures, in: *The SDI Cookbook*, Version 1. http://www.gsdi.org/pubs/cookbook/

Kresse, W., Fadaie, K., 2004, *ISO Standards for Geographic Information*, Springer, Berlin, p. 322

Strobl, J., Roth, C., 2006, *GIS und Sicherheitsmanagement*. Wichmann Verlag, Heidelberg, p. 188

TUM, 2005, Feuerwehr Technische Universität München, Brandschutz **1:**30–33

Internet resources (last visited November 2006)

http://www.oasis-fp6.org – Project OASIS

http://www.denis.bund.de/ – deutsches Notfallvorsorge – Informationssystem – German emergency preparedness information system

http://www.opengeospatial.org/ – Open Geospatial Consortium

http://www.isotc211.org/ – International Standardisation Organisation