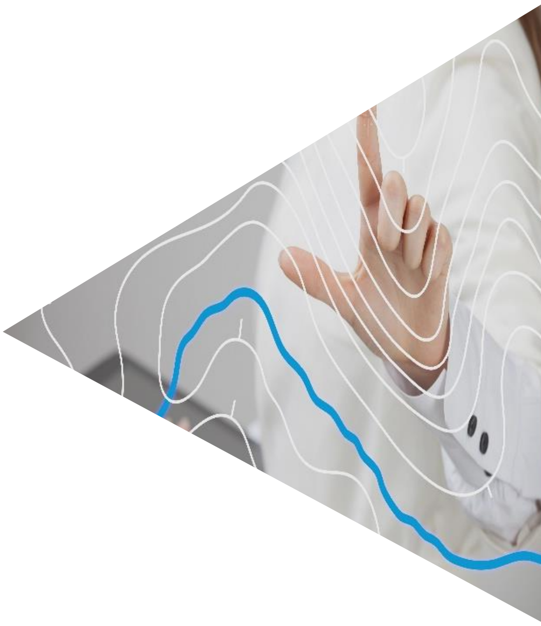
The value of

Spatial Information

for Emergency Services

How can spatial information be integrated into emergency response? What are the benefits and challenges to address?

The Value of Spatial Information for Emergency Services



Title: The Value of Spatial Information for Emergency Services (update of GIS for Emergency Services)

Version: 2.0 - Published 18/05/2020

Version 1.0 – Published 16/01/2017

Status of the document: APPROVED

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EXECUTIVE SUMMARY

Spatial information can have significant value in emergency management. Many benefits can arise from integrating technologies to support spatial decision-making into the field, as the aim is the reduce or avoid potential losses from risks and hazards, assure prompt and appropriate response, and achieve rapid and effective recovery. Access to complete, credible, easy-to-use, and timely provisioning of spatial - and non-spatial - information about geographical objects and factors, as well as their influence, become the prerequisites for making the right decisions or supporting geographical inquiries.

The development of aerospace technologies with remote sensing, location, and navigation services, leverages the penetration of spatial information in all phases of emergency management: mitigation, preparedness, response, and recovery. Therefore, Geographic Information Systems (GIS) deliver a valuable spatial framework for addressing many problems that arise in the context of emergency management. EU-wide standardisation efforts of spatial data, which is increasingly online accessible, accompany this journey.

Overall, the paradigm of "map-centric" visualisation and analysis at the dispatcher workplace is more and more complemented by the introduction of several sources of shared spatio-temporal information – in real or quasi-real time if necessary. Accordingly, spatio-temporal data management and its flexible deployment is pivotal for spatial awareness everywhere, from any device. This implies new challenges, but also offers new and efficient features and services for robust and secure emergency operations. Thus, emergency services operations are encouraged to transition towards a service oriented, spatio-temporal data service delivery and service management organisation, where the ability to cope with a constantly changing real world can be improved.

Spatial information can have an enourmous value for emerency services organisations. This document aims to demonstrate and discuss the uses of integrating such data into emergency response.

1 | INTRODUCTION

The development of aerospace-based technologies and services, with improved remote sensing and communications capabilities, accelerated the comprehensive penetration of spatio-temporal information in every phase of the emergency management cycle (mitigation, preparedness, response, and recovery). Without any doubt, spatio-temporal information has become a mission-critical attribute which offers tangible benefits for emergency services. However, it also requires a thorough definition of requirements and feasibility analysis, tests, and the implementation of a flexible and efficient spatio-temporal data management.

More than 72% of emergency calls in the EU are from mobile devices[1]. The smart-phone penetration rates easily exceed 60% in the member states[2]: citizens take ambient location information in daily life for granted. Therefore, upcoming location/routing services in the emergency services network infrastructure utilise spatial data services in Next Generation 112 architectures (NG112) for efficient emergency call handling.

Global Navigation Satellite Systems (GNSS) deliver accurate positions and enable tracking and navigation support, which is accompanied by emerging indoor location technologies e.g. Wi-Fi, iBeacon. In combination with these mobile technology advancements, spatial intelligence no longer resides exclusively in the control room. In fact, geodata can be accessed from anywhere with almost any device. This resolves, for instance, potential issues in getting accurate information back from field operations to the command centre and vice-versa (field enablement).

[1] *Implementation of the single European emergency number 112 – Results of the thirteenth data-gathering round: https://ec.europa.eu/digital-single-market/en/news/2019-report-implementation-european-emergency-number-112*

[2] *Digital economy and society statistics - households and individuals: https://ec.europa.eu/eurostat/statistics-explained/pdfscache/33472.pdf*

With EU-interoperability and standardisation activities for spatial data interfaces and infrastructures as a key enabler, geo-information merges towards standardised and interoperable base datasets. This eases cross-border and multi-agency interoperability. Accordingly, existing local geo-databases maintained by emergency services can be orchestrated with various shared geo-information sources. Hence, the prevalent "map-centric" visualisation approach of a digitised map at the dispatcher's workplace is accompanied by available base and thematic geodata.

Even real-time or quasi-real time processed spatial information can be acquired and more easily integrated from emergency management services like the EU Copernicus initiative in case of disasters, or by self-operated unmanned aerial systems (UAS) and unmanned vehicles (UVS), including improved imagery algorithms and smart sensor solutions. Improved situational awareness and decision support can be provided "on-the-fly." Examples include special response teams in terrorist attacks, weather related disasters, crisis management centres, field staff safety and support. Besides, the driving consumer market will continue to reduce currently expensive geodata acquisition and reduce the effort to process aerial image.

It becomes obvious that the key challenge for emergency services is being able to discover, access, integrate and share spatial information with its users. Geodata management is expensive and requires skilled resources to cope with lack of data or weaknesses of existing data. Resources are also required to keep pace with a constantly evolving world, whilst also meeting quality decision standards, complying with IT security and data privacy regulations, and ensuring guidelines are respected. Hence, emergency services are encouraged to enter a transition process towards a service-oriented spatial data service delivery and service management organisation. This aims to utilise technology enablement and maintain a sufficient geodata quality level in emergency management processes where lives and property are at stake.

The subsequent sections discuss the application of Geographical Information Systems (GIS) as a means for geographical inquiry in the emergency management phases and provide scenarios where spatial decision making for faster response & relief is required. A brief discourse in geodata management, from early acquisition, provisioning, maintenance, and distribution with hints, sources and examples, complements the application perspective. The final chapters conclude the findings and share recommendations for the involved parties.

1.1 | DEFINITIONS

A Geographical Information System (GIS) is defined as a computer-aided system for geographic data management, modelling, analysis, simulation, and presentation. A GIS is an organised collection of computer hardware, software, geodata and skilled operators. It is an integrated mapping system that takes words, numbers and other data that can be correlated to geography (i.e. location) from a database and visualizes them on a map, making the information easier to understand, analyse and work with.

More precisely, it is spatial representation, capture, storage, retrieval, analysis, and display of information (attribute data) that is positioned to correspond to the same X, Y, Z and t coordinates (latitude, longitude, height and time) throughout the various map layers. Its main goal is to provide insights on a specific situation and support the user in taking the most appropriate decisions.

GIS uses datasets with a spatial aspect or component which can be defined as Geodata (also “spatial data”, “geographic data”, “geographic data sets”, “geoinformation”, or “GIS data”). Geodata has a spatial, temporal, and thematic aspect, can be linked to other data sources and represents the core value of geographical information systems. Hence, spatial queries, analysis and simulations can be conducted if such larger and complex data structures can be managed. It is appropriate to distinguish between spatial base data and thematic data as a subset of geodata.

- Geographic base data is usually provided by national or international surveying and mapping agencies. It includes mainly topographic information stored in maps or landscape models. Satellite and aerial images can also be regarded as spatial base data, as long as they only provide topographic information in the human-visible bands.
- Thematic data is acquired by specific domains. Thematic data can but does not necessarily have to include a geometry component. It is often linked to spatial base data using coordinates, administrative units, full addresses, or zip codes. Examples include soil data, geology data, geostatistical data, weather data, meteorological and oceanographic information, etc.

Base and thematic data are complemented by operational data of the public safety and emergency management context (e.g. vehicle and staff positioning, access routes and tactical zones, hazardous areas, building plans, soil type, vegetal coverage, among others).

1.2 | GIS STANDARDISATION PROCESS

The introduction of appropriate standards in collecting, preparing and maintenance of spatial information enables their use in various applications, regardless of the source. International standards give organisations a way to abstract their process functionality in such a way that they will be able to swap in and out of vendors or use open source components. Geospatial standards are becoming increasingly important now, especially when international, regional, and national bodies are trying to build or/and harmonise their Spatial Data Infrastructures (SDI).

Guided by this principle, most European countries, as well as several international organisations invested considerable effort and resources into the creation of standards of Spatial Data Infrastructure. Regional and national efforts led to the launch of initiatives to create and adopt global standards in the scope of the International Standardization Organization (ISO), as well as regional standards within the European Committee for Standardization – Comité Européen de Normalisation (CEN).

International standardisation

ISO/TC (Technical Committee) 211[3] geographic information standards specify methods, tools, and services for data management (including definition and description), as well as acquiring, processing, analysing, accessing, presenting, and transferring such data in digital/electronic format between different users, systems, and locations. The ISO/TC 211 family of standards defines rules and standardised schemata for the definition and description of geographic information and information management.

Regional standardisation

A pan-European body called CEN is the main regional European standardisation body and operates through the European Commission. CEN/TC (Technical Committee) 287 (Geographic Information) is responsible for the development and publication of geographic information standards. In the Geographic Information area, CEN works closely with the ISO. CEN standards are mandatory in Europe.

Industrial Consortia

One of most active industrial consortia involved in geo-spatial standard development and promotion is the Open Geospatial Consortium (OGC), formerly the Open GIS Consortium[4]. OGC has concentrated its efforts on the following areas:

- Encoding information in software systems (data format standards and data transfer standards);
- Naming features and feature relationships (data dictionaries);
- Schema for descriptions of data sets (metadata).

[3] *http://www.isotc211.org/*
[4] *http://www.opengeospatial.org/standards*

The OGC works closely with ISO/TC 211. Many common work items exist between the OGC and ISO/TC 211 that result in OGC specifications being adopted as International Standards or Technical Specifications.

There are some differences between ISO and OGS procedures and products. ISO/TC 211 is the de jure formal standards technical committee. OGC is the de facto industry technical specification developer. ISO standards have a formal life cycle that include official approval, publication, and periodic revisiting. All international standards are reviewed at least once every three years (after publication) and every five years (after the first review) by all the ISO member bodies. OGC specifications can be utilised by users before formal approval and could be updated a few times in any given year.

The INSPIRE Directive

In a major effort to normalise spatial information within the EU, the European Commission established the INSPIRE[5] (Infrastructure for Spatial Information in Europe) initiative, on 15 May 2007, with full implementation required by 2019. INSPIRE aims to create a European Union (EU) spatial data infrastructure. This enables the sharing of environmental spatial information among public sector organisations and better facilitates public access to spatial information across Europe. A European Spatial Data Infrastructure will assist in policymaking across boundaries. Therefore, the spatial information considered under the directive is extensive and includes a great variety of topical and technical themes. It covers more than 20 thematic clusters[6] which are partially relevant for emergency services. Examples include human health and safety with locations of hospitals, police stations, PSAP location and service areas, population areas, natural risk zones, energy resources, buildings, elevations statistical units, and ortho-imagery. INSPIRE uses CEN/TC 287, ISO/TC 211 and OGC standards and specifications.

ISA^2 Programme

The ISA² programme (interoperability solutions for public administrations, businesses, and citizens) was launched in early 2016. It supports the development of digital solutions that enable public administrations, businesses, and citizens in Europe to benefit from interoperable cross-border and cross-sector public services. Along with INSPIRE, its sub-activity – European location interoperability solutions for e-government (ELISE)[7] – was established to remove obstacles to the efficient sharing and re-use of geospatial information. Legal/policy, organisational, semantic, and technical interoperability requirements that will facilitate efficient and effective electronic cross-border and cross-sector interaction in the area of location information and services will be covered.

[5] *http://inspire.ec.europa.eu*
[6] *https://themes.jrc.ec.europa.eu*
[7] *http://ec.europa.eu/isa/actions/isa2/04-geospatial-solutions/10action-en.htm*

2 | GIS FOR EMERGENCY SERVICES' PROCESS IMPROVEMENTS

It is commonplace in PSAPs that geodata are used to provide accurate location information to dispatchers and first responders. However, GIS takes mapping far beyond simply showing specific locations, such as a street address or an intersection. GIS automates mission-critical tasks by submitting optimised response proposals by status, location, and time-to-incident location. This is complemented by routing calculations, to improve response times and situational awareness, leading to more effective incident resolution.

Geodata can also be used to deliver a great deal of additional thematic information concerning the relationships between people, places, time, and things. Physical locations as points-of-interests, objects like schools or risk-prone areas can be correlated regarding their proximities and relationships between and among key community structures. In conjunction with the location of response teams, assets like video surveillance cameras, healthcare facilities, and fire and police stations, communities are better prepared for potential risks and hazards according to their local risk register. The subsequent paragraphs share some examples of GIS and geodata used in the mitigation, preparedness, response, and recovery phase of emergency management. They also point out a few key future scenarios.

2.1 | USAGE OF GIS IN DIFFERENT PHASES OF EMERGENCY MANAGEMENT

PLANNING & MITIGATION: Evaluating the potential types of disaster and developing plans for reducing their probability or their impact on life and resources.

GIS can aid understanding of the geography of vulnerability. It is hard to predict exactly what could happen in an emergency situation. However, even a rough estimate can be a huge help to emergency managers and decision makers when developing plans for resource allocation and management of the investigation and recovery operations. By collecting socio-economic and environmental data sources in a GIS, one can develop risk maps to highlight the potential impact of disasters on people and infrastructure.

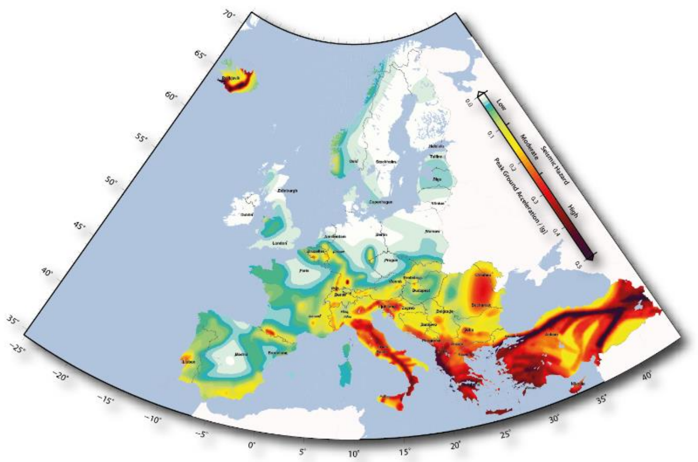


Figure 1: European Seismic Hazard Map[8]

In this phase, several major questions need to be answered, such as:

- Who is at risk? How many people will be affected?
- What is the spatial and temporal extent of the vulnerability?
- What capacity does the population at risk have for coping with the disaster?
- What is the range of possible victim scenarios given different conditions?

The use of GIS can also help to assess the spatial and temporal distribution, such as areas which have the highest concentration of known gang members, or to analyse burglary series helping to identify patterns. This can help to provide forecasts for mitigation measures (predictive policing) to enhance community safety.

[8] *http://www.share-eu.org*; Project SHARE (Seismic Hazard Harmonization for Europe); reference to European Facilities for Earthquake Hazard & Risk (EFEHR) at *www.efehr.org*

PREPAREDNESS: Actions undertaken when mitigation efforts have not prevented or are unable to prevent a disaster from taking place.

GIS is a key element of disaster preparedness through computational simulation and modelling. Wide arrays of specialised modelling software extensions are available. This enables users to tweak disaster parametres and simulate damage patterns due to natural disasters, pandemics, or fires. Different disasters present different types of opportunities for preparedness. Some, like terror attacks or earthquakes provide little or no warning time at all. Others, like hurricanes or other severe storms, may offer a window of preparation time, where GIS is used to coordinate evacuations and other types of preparation efforts (sandbagging levees, for example).

One way to prepare for disasters that offer little or no warning is to develop spatial computational models of disaster impacts and use a GIS to run simulations of hypothetical emergency situations. A second part of preparedness regards training. The GIS usage in support of operations training is paramount on any system. The GIS, as any other tool in the emergency personnel arsenal, needs to be used in day to day operations and within training for any incident type.

RESPONSE: Activities that occur in the wake of a disaster that are intended to identify and assist victims and stabilise the overall disaster situation.

Here comes the real-time GIS usage: one of the most important features of the system. An example of the use of a GIS application in PSAPs can be found in EENA's case study: *GIS 112 in Estonia*.[9] More about this is discussed in the following chapters (Situational Analysis, Optimised Routing and Enhanced Analysis).

RECOVERY: Actions following a disaster to restore human and environmental systems back to normal.

Recovery from a disaster can take a very long time and there are a wide range of roles that GIS can play in the recovery process. For example, GIS may be called upon to identify areas for redevelopment projects or to recalibrate vulnerability models to help predict future disaster impacts.

[9] *https://eena.org/document/gis112-in-estonia/*

2.2 | GIS & SITUATIONAL ANALYSIS

GIS deliver detailed situational awareness for dispatchers and first responders by geographically tying persons, processes, and data together. Dispatchers, police officers, fire-fighters, and emergency medical technicians (EMTs) can access a common view of information, from street maps and agency boundaries to real-time or quasi-real time localisation of events, equipment or personnel. This may also involve information on infrastructures (utilities, hospitals, etc.), risks, and hazards, giving a complete view of the operations area. Each one of the elements at hand are located via latitude, longitude, height, and time.

These integrated map views help them to assess the situation at a glance. They can be enhanced by overlaying other information pertinent to the safety and security of each operator in the area. Information like gang territories, localisation of older people or schools per type and number of students etc. allows for a better understanding of the equipment and measures needed for the overall mission. Other data — such as live video from street cameras or images sent from mobile phones — can also be displayed to enhance awareness and safety. As each responder can view exactly what others are seeing, it is also faster and easier to collaborate and coordinate with other jurisdictions and agencies.

Video integration enables point-and-click control of video cameras; security personnel can easily control camera movement such as pan, tilt, and zoom by pointing and clicking on a map. GIS-enabled video surveillance provides security for law enforcement personnel with live video, as well as the spatial knowledge to best respond to any threat. The access to some of the information needed may be protected or restricted, so the GIS needs to guarantee that all the access authorisations are maintained under strict rules.

Figure 2: Layered data

2.3 | NEXT GENERATION NETWORKS AND ARCHITECTURES (NG112)

GIS helps PSAPs solve many of today's call processing issues. In legacy systems, for example, GIS data is normally accessed *after* the call reaches the PSAP and permits dispatchers to locate the caller. Efficient and effective response can be compromised due to missing or incomplete geographic data. This can lead to incorrect or imprecise caller location determination and misinformation when directing responders to the location of an incident. This can cause significant delays in response that may be life threatening for both citizens and responders.

In Next Generation 112 (NG112) systems, however, the comprehensive use of GIS datasets helps eliminate the manual caller location lookup of today's traditional address databases. Instead, using a more accurate position provided by the calling device itself and/or the mobile network operator, and GIS data representing the PSAP service areas, the call is automatically routed to the correct PSAP. This reduces the number of misrouted calls and the dispatch can therefore be faster and more accurate.

Civic addresses are also being considered in standards as "dispatchable" addresses e.g. *0112 Church Street West, 2nd.floor apartment 410, Nowhere county*. This will give call takers additional information for the validation of the location and ultimately reduces response times.

The more accurate emergency caller location is, the more capable PSAPs are to efficiently handle emergency calls. PSAPs can develop their ability to coalesce spatial information, creating seamless maps from other neighbouring jurisdictions. This enables call takers to identify emergency locations or search for locations outside of their region: a valuable measure for creating borderless boundaries in map displays. As standardised spatial interfaces and services have matured, the prevalent "map-oriented" geodata set as a self-contained information silo in the PSAP is complemented by the use of distributed spatial information. This fosters collaboration and interoperability between emergency services. Call takers and dispatchers will be able to provide quick and effective response, even in cases where emergency callers might be located near, but not within, a PSAP's jurisdiction.

2.4 | REAL-TIME OR QUASI-REAL TIME SPATIAL ANALYSIS

2.4 | REAL-TIME OR QUASI-REAL TIME SPATIAL ANALYSIS

With the orchestration of sensor data and existing thematic data, it is possible to perform further real-time or quasi-real time analysis in the command centre. For instance, social media messages can be queried for specific key words in the vicinity of an emergency call location. In addition, routing assistance for dispatchers is possible, for example "*present closest hospitals in an incident area*".

By enabling real-time or quasi-real time mapping of events and objects, GIS is capable of illustrating a wealth of information that is tied to a location or area, all at a glance. Meteorological and oceanographic data, operational data like plumes of gases, fire propagation in a specific environment, or response team localisation, can be mapped with additional geospatial datasets. This reveals patterns that might go unrecognised without this functionality. For instance, agencies are able to analyse traffic accidents to better view, understand and investigate geographic patterns. Using this information can help to remedy or resolve recurring problems in certain locations, such as intersections and neighbourhoods, or access models that will help to locate equipment and personnel to manage an emergency.

2.5 | BIG DATA SPATIAL ANALYSIS

This is an area of GIS analysis that supports the analysis of information fostered by IOT (Internet of Things) mega trends. The time-enabled data from sensors and social media tends to grow exponentially in any given incident. This implies that the GIS analysis will need to support big data.

The main question here reflects the need to process and analyse large volumes of data in very small timeframes. A different approach to analysis is therefore needed. However, it provides a new level of abstraction and, hence, new insights on patterns from the incident that are important within the command and control processes.

We need, however, to be aware that this can have major implications regarding computing capacity that, to be solved, may imply the recourse to cloud computing.

2.6 | INDOOR LOCATION AND MAPPING

It must be acknowledged that a fair number of incidents occur indoors, and many times in public buildings or private areas such as universities, arenas, and sports facilities. GIS enables emergency services to collect and visualise indoor building maps, which contain all relevant building information including room numbers, floors, doors, objects, and facilities.

Such sensitive objects and sites can be spatially modelled and complemented by real-time location information of callers inside buildings. They may also support university campus evacuation activities, for example. In this way, GIS becomes a valuable tool for decision support to efficiently conduct Search and Rescue (SAR) or establish countermeasures, for instance during terror attacks. As the accuracy of indoor location improves through initiatives such as *Advanced Mobile Location* (AML) and Wi-Fi and beacon positioning technology, geodata must evolve in parallel to allow call takers, dispatchers, and responders to accurately locate callers indoors by providing a visual base, or reference. It is anticipated that indoor geodata provisioning can also be used to complement radio communication coverage inside of buildings in order to improve self-protection of the response personnel on the field.

Building information modelling (BIM), used inside the GIS, provides a proper view of the building interiors essential to enable indoor navigation. Acquisition of these models needs an active cooperation with the proper authorities, which need to gather the relevant information.

2.7 | MOBILE SPATIAL APPLICATION

Mobile technologies enable a tighter collaboration between command centres and field staff, as spatial and incident information can be conveniently shared in a two-way communications pattern. Information is therefore available everywhere, such as caller name, address, incident type, incident locations, object information, relevant geodata of the area with safety hints, access information, the involved field staff location and their status, and possible associated further incidents in the vicinity.

As existing sensors like surveillance cameras have become a geo-referenced asset, real-time access to the most applicable cameras from mobile devices and the command centre can be enabled. This applies also to further emergency calls in the area, where routing services utilise the deployment of a mobile command centre where all calls in the neighbourhood can be answered. Overall, mobile spatial applications are the key means to providing a contextual spatial and task-oriented operational picture in real-time for staff and incident commanders in the field.

2.8 | MOBILE SPATIAL APPLICATION

The increasing geodata quality makes it possible to visualise the third or fourth dimension as well as using increasingly accurate and rapidly available (real-time) GIS solutions. With 3D point clouds[10], the world defined by X, Y, and Z coordinates can be imaged with a high level of detail, as the utilisation of drones and advanced sensor technologies makes the cost-efficient automatic derivation of 3D city models feasible. Buildings and objects with textures and roof structures (Level of Detail 2 - LoD 2) have become a standard resolution,and this level of detail is frequently combined with the existing 2D maps, thematic data and aerial images.

In parallel, mobile technologies, accompanied by standardisation work, extend the level of detail of the emergency caller location. Elevation, in the form of Z-axis data is added to geodetic locations, enhancing them from today's 2-dimensional X/Y points to 3-dimensional X/Y/Z points. This emergency trend offers PSAPs a contextualized 3D representation of an incident area.

Police services employ 3D city models for preparation of demonstrations and their safeguarding, for instance with analysis of possible escape routes and barriers. For this purpose, the city development plan and vegetation and street visualisation are needed to provide an accurate overview of the area. Efficient evacuation planning in urban areas prior to public safety bomb disposal (PSBD) is also supported, as well as the identification of access routes, potential blockings, or the determination of response teams' positions with direct line-of-sight in case of terror attacks, siege or man hunt.

Fire and rescue services find 3D city models particularly important during hazardous material accidents - accidents in plants with toxic, environmentally hazardous and flammable substances - as the threat area with adversely impacted population, objects, infrastructure and environment can be analysed and visualized. Overall, 3D model technologies have created a considerable number of research papers[11] and continue to be considered in future GIS deployments in emergency management.

Building information modelling (BIM) provides extended 3D information to support the 3D model.

It should be clear that accurate 3D models are still expensive to acquire and maintain. A concerted effort between all the entities interested in using 3D data needs to be made to support the needed models.

[10] *https://en.wikipedia.org/wiki/Point_cloud*
[11] Applications of 3D City Models: State of the Art Review; *http://www.mdpi.com/2220-9964/4/4/2842*

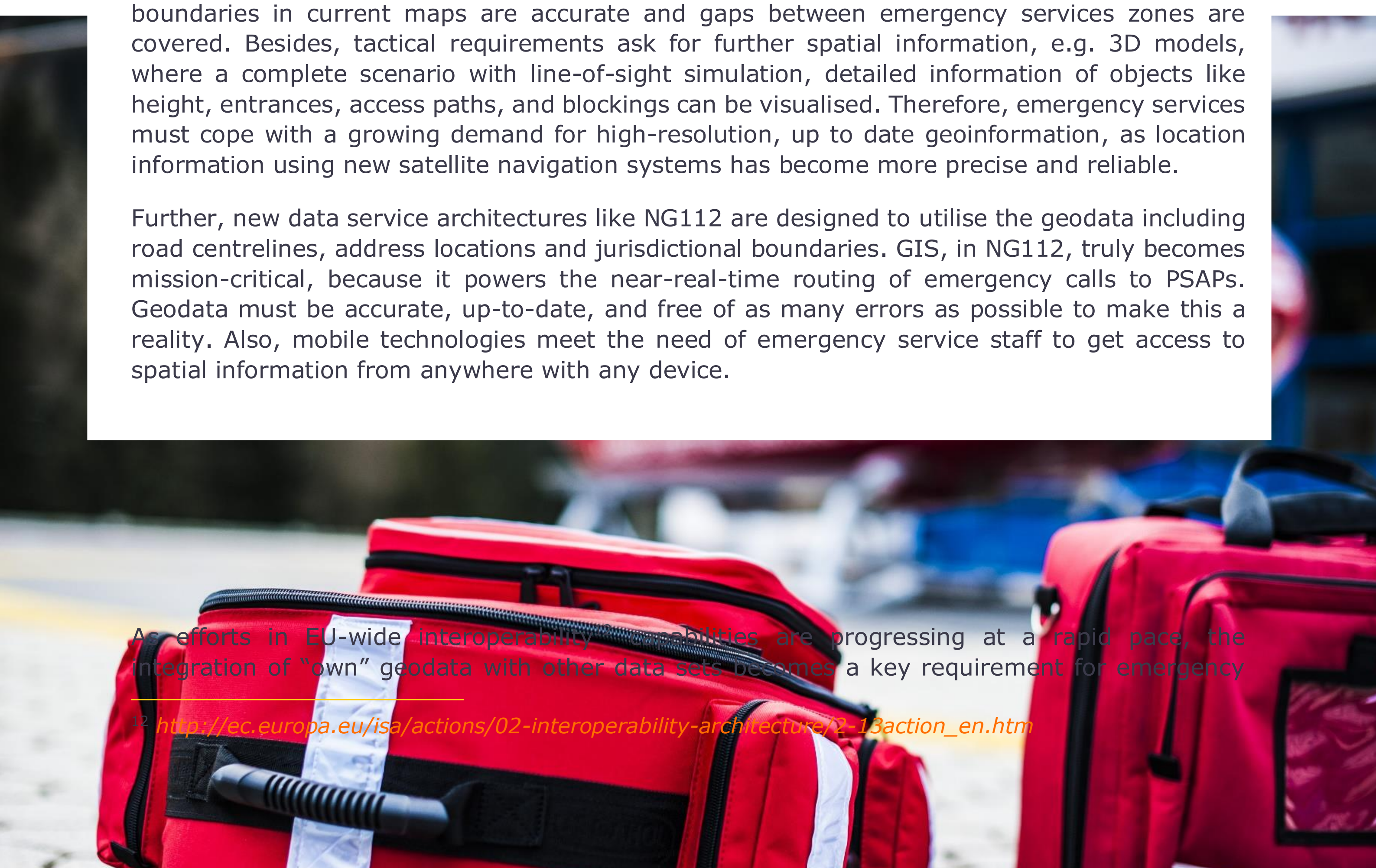
3 | GEODATA MANAGEMENT

Emergency services organisations require exceptionally well-organised communications between different actors, providing timely information in an immediately understandable and clear format where spatial awareness is a critical capability. Fundamentally, a GIS system is only as good as its data, and data accuracy is essential for Next Generation emergency call systems to deliver substantial benefits.

The reality is that when there are delays in emergency call response today, they are primarily due to data inaccuracy or missing and incomplete data. This is a major concern of today's public safety professionals worldwide. Geodata accuracy issues and update cycles – such as the accuracy of address data and the time it takes to incorporate address updates in GIS data - are a problem to a certain degree for virtually every PSAP in every city, region, state, province or country. Furthermore, it is important to highlight that the risks of obsolete information for decision makers are enormous.

Geodata as representations of the real world are *per se* not static; they are evolving and changing continuously. The number of geoinformation sources and sensors significantly increases, driving interoperability requirements, and creating a burden for geoinformation management. New roads, buildings, addresses, objects, and infrastructure are constantly being added in the service zones. Existing address databases must be synchronised to assure that boundaries in current maps are accurate and gaps between emergency services zones are covered. Besides, tactical requirements ask for further spatial information, e.g. 3D models, where a complete scenario with line-of-sight simulation, detailed information of objects like height, entrances, access paths, and blockings can be visualised. Therefore, emergency services must cope with a growing demand for high-resolution, up to date geoinformation, as location information using new satellite navigation systems has become more precise and reliable.

Further, new data service architectures like NG112 are designed to utilise the geodata including road centrelines, address locations and jurisdictional boundaries. GIS, in NG112, truly becomes mission-critical, because it powers the near-real-time routing of emergency calls to PSAPs. Geodata must be accurate, up-to-date, and free of as many errors as possible to make this a reality. Also, mobile technologies meet the need of emergency service staff to get access to spatial information from anywhere with any device.



As efforts in EU-wide interoperability[12] capabilities are progressing at a rapid pace, the integration of "own" geodata with other data sets becomes a key requirement for emergency

[12] http://ec.europa.eu/isa/actions/02-interoperability-architecture/2-13action_en.htm

services operations. The implementation of a geospatial data infrastructure must provide interoperable data and services based on commonly agreed standards, to enable emergency services to build and execute their work. This operational requirement describes how to acquire, provide and update spatial data, as well as how spatial data are shared and utilised (**Error! Reference source not found.**).

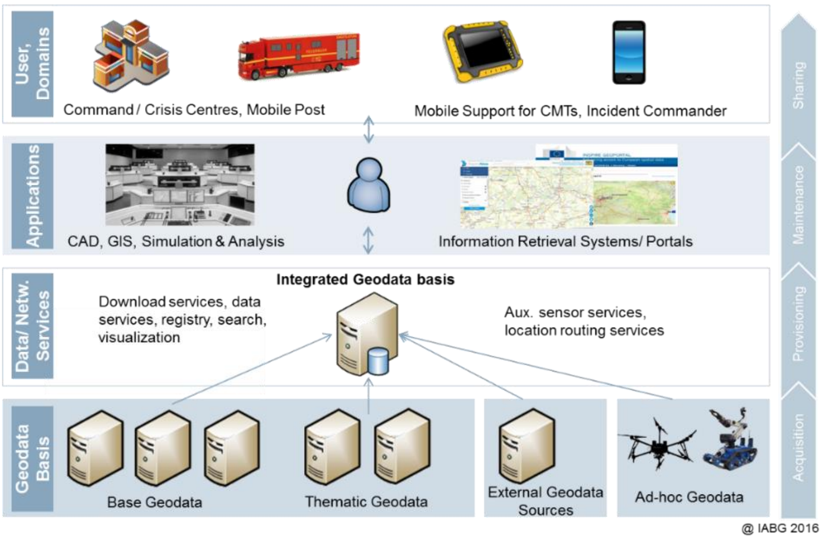


Figure 3: Emergency services geodata infrastructure framework

3.1 | GEODATA ACQUISITION

Geodata acquisition ensures the collection of geodata for further processing. It comprises geometry (spatial information), date and time (temporal information) and any non-graphical related attributes (thematic information).

Primarily, geodata are directly derived from the objects monitored via terrestrial surveying, photogrammetry, and remote sensing[13] methods which predominantly produce topographic base data. Photogrammetry in this context allows measurements from pictures and photographs and is a cost-effective method to provide detailed topographic data. Hereby, a collection of images about a larger area is mapped into a single model, and the orientation of this model is processed by extracting 3D vector coordinates to describe geographic objects (ortho-images).

Besides, secondary geographic data are derived from such primary data sources. It is quite common to develop digital data by scanning maps or aerial images to be georeferenced and to provide the geographic context for other data, e.g. relevant information for emergency services regarding areas, buildings. In addition, vector data can be generated by converting raster data

[13] *https://en.wikipedia.org/wiki/Remote_sensing*

into vector objects. It is likely that secondary data are of lower quality and less up to date. For example, data processing from smaller scale maps carries generalisation effects that result in a lack of accuracy of object selection or displacement.

In addition, fieldwork and monitoring sensors (e.g. water gauges, weather stations), complemented by results of interviews, census and polls result in comprehensive thematic data sets. Both acquisition methods are significantly facilitated by the development of space-based assets: a *Global Navigation Satellite System* (GNSS) in conjunction with mobile technologies. It becomes obvious that geodata is frequently based on complex data structures, which is expensive to acquire and manage and carries special skills in information processing.

3.1.1 | SPATIAL DATA TYPES

Geodata are defined in spatial data models which conceptualise how spatial information is arranged in a computer system. These data sets refer to a coordinate system (geo-reference) to locate the information on the surface of the earth, to align data relative to other data, to perform spatially accurate analysis, or to create maps[14].

Several coordinate systems exist, thus creating additional complexities with projections and transformations to coherently present such datasets. For instance, the eCall location information is based on the World Geodetic System (WGS84) coordinate system. Due to the operational nature of this document, further technical details will be avoided. The focus of the subsequent sections is the two main basic data models – raster and vector format - in the context of the geodata acquisition.

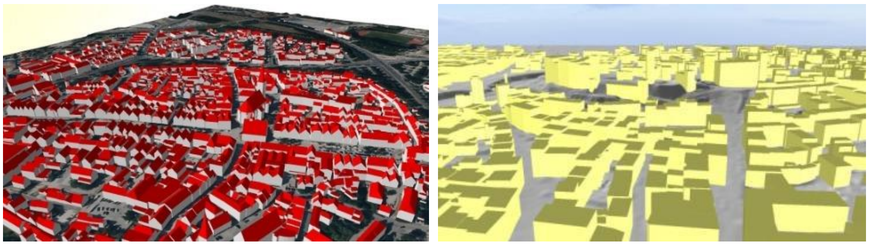
Vector data

Vector data[15] are a coordinate-based data model that represents geographic features (objects) as points, lines, and polygons. Each point feature is represented as a single coordinate pair, while line and polygon features are represented as ordered lists of vertices. Attributes are associated with each vector feature, as opposed to a raster data model, which associates attributes with grid cells. With these attributes, the geometry is associated with the thematic information. For instance, lines could represent everything that has a length: underground and overhead cables, communication systems, roads, and rivers, among others. The shapes and polygons represent everything that fits within a limited area, either political, natural, or administrative boundaries (state, municipalities, cities, parcels, PSAP service areas etc.). Therefore, vector data are necessary to represent real world features in a spatial analysis in a GIS. For example to find the nearest PSAP, hospital, or fire station.

Example: 3D building model / 3D city model. Three-dimensional building information based on building footprint and height information which is usually offered by ordnance survey agencies.

[14] *https://pro.arcgis.com/en/pro-app/help/mapping/properties/coordinate-systems-and-projections.htm*
[15] Basis: *https://support.esri.com/en/other-resources/gis-dictionary/term/7cbd3f7c-e17f-4bb0-a51a-318ccf5b68f1*

This is a model which can be used for line-of-sight simulation, emergency staff positioning, and general resource planning.



LoD-2 LoD-1

Figure 4: LoD 3D models

Raster data

Raster data[16] describe spatial objects based on pixels, whereas a pixel in addition to its position contains only one information. Frequently, raster data are used in a GIS as a background image for other GIS-layers. For example, ortho-images displayed underneath other layers ensure that the map layers are spatially aligned and represent real objects. Raster data can be created from satellite images, aerial photo images (ortho-photo), scanned data (analogue paper maps into digital format), or sensor data like radar data and laserscan data.

Raster grids are well suited for representing data that changes continuously in a landscape (surface map). They provide an effective method of storing the continuity as a surface. Elevation values measured from the earth's surface are the most common application of surface maps, but other thematic data, such as rainfall, temperature, wind, contamination areas, and population density, are available for spatial analysis. As an example, a digital elevation model (DEM) is a digital model or 3D representation of a terrain's surface:

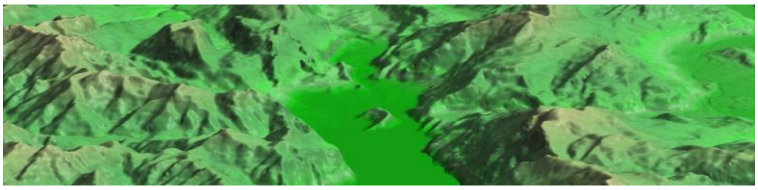


Figure 5: Example of digital surface model (upper Garda Lake area) at 25m

[16] Basis: *http://desktop.arcgis.com/en/arcmap/10.3/manage-data/raster-and-images/what-is-raster-data.htm*

DEMs are available in different resolutions, (e.g. 1m, 25m, 30m, 200m) for defined geographical areas. Depending on the grid size, they are available free-of-charge (e.g. EU-DEM for Europe with 25m grid size from the European Environment Agency (EEA)[17])

Raster data representing thematic data can be derived from analysing other data. For instance, if a satellite image is classified by land-cover categories or additional multispectral data are applied, or existing vector, raster, and terrain data are combined and processed for specific activities. Examples of uses include crime risk zones and potential flooding areas, among others. Raster data offer the possibility of obtaining rapid spatial data for large areas and is significantly less demanding of time and money than vectorising map layers one by one. It offers a simple data structure suited to advanced spatial and statistical analysis.

On the contrary, the picture is still one file, or one layer, from which it is not possible to take out a specific object and associate it with thematic data. One must consider that there are spatial inaccuracies due to the limits imposed by the raster dataset cell dimensions. These datasets are also potentially very large, especially for high resolution images.

Geodata converters allow existing raster data to be transformed into vector types. Images can be displayed together with vector data, so-called hybrid graphics, which enables vectorization of only those objects that are essential for the work.

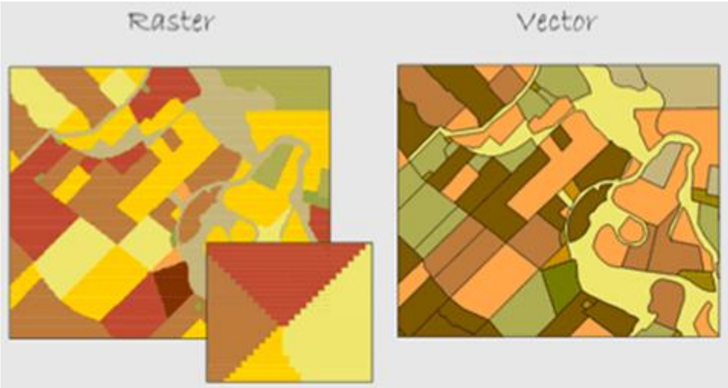


Figure 6: Comparison of raster data and vector data[18]

<u>Note:</u> Geodata are encoded in a variety of different formats (geofile formats). Most of them are proprietary, some of them related to a specific country and some related to manufacturers. However, a multitude of tools and applications are available to access, modify, reuse and present geodata through application programming interfaces (e.g. OGC), or to perform file format conversion, for instance in case of GIS migration activities. The translation process must address both syntactic and semantic problems, whereas the latter is an inherent issue of geodata.

[17]*https://www.eea.europa.eu/data-and-maps/data/copernicus-land-monitoring-service-eu-dem*
[18]*http://giscommons.org/introduction-concepts/*

3.1.2 | SATELLITE IMAGES

Satellite image are images of the whole or part of the earth taken by satellites[19] in a sun-synchronous orbit or geostationary location in altitude between 200 – 36.000km. The images serve a variety of uses, including cartography, intelligence, meteorology, climate and environment.

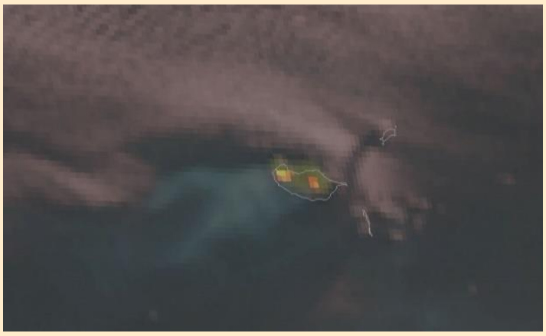
Therefore, satellites are equipped with a variety of multispectral sensors with different resolutions to submit visible images, radar images, water vapour images or infrared images, depending on the purpose. High resolution pictures are costly. Generally, satellite images are weather dependent due to potential cloud coverage in the monitored area.

Table 1: Selected sensors and provisioning services

Sensor	Actuality	Price	Provider
Pleiades	Emergency Services: 24h	€	Airbus Defence and Space (France)
Spot 6/7	Emergency Services: 24h	€	Airbus Defence and Space (France)
Rapid Eye	Priority Tasking: <45 days	€	BlackBridge
Sentinel-2	Archive: 10 days	Free of charge	ESA-Copernicus
Landsat 8	Archive: 16 days	Free of charge	NASA, USGS (USA)

19 https://scihub.copernicus.eu/

Table 2: Satellite image examples

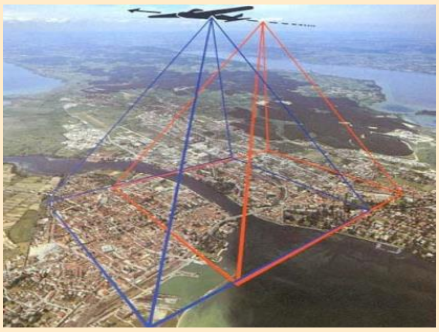
Very High Resolution	**High Resolution**
- WorldView-3: 0,3m - GeoEye-1: 0,4m - Pleiades: 0,5m - SPOT 6/7: 1,5m	- RapidEye: 5m - Sentinel-2: 10m - Landsat8: 15m
	
www.digitalglobe.com (Flooding Madagascar 2015), WorldView-3	www.satimagingcorp.com (Burghausen Germany), RapidEye
Medium Resolution	**Low Resolution**
- Landsat 1-5: 30m - Deimos: 22m	- Meteosat: 2500m
	
www.usgo.gov (Tschernobyl ,1986) Landsat 5	www.eumetsat.int (Fires on Madeira, August 2016)

3.1.3 | AERIAL IMAGES

From an original aerial photograph, an ortho-image can be derived by computational equalization, which is characterised by exact scale and spatial reference. Digital ortho-images form the basis to produce aerial maps.

The terrain is represented in scale and in the correct position. Dimensions and coordinates can be associated with other base geodata or combined with further thematic data due to the consistent spatial reference. Aerial images are relevant for incident management and emergency planning purposes.

Table 3: Aerial images

Aerial image	Orthoimage
 *www.lgl-bw.de*	 *www.ldbv.bayern.de/produkte/luftbild/orthophotos.html*

Drone footage

Meanwhile, there are several solutions available which enable emergency services to collect and process aerial images captured by Remotely Piloted Aircraft System (RPAS) (drones). Photogrammetry software, available on the market, can utilise live-video streams or pictures of an affected area to create professional ortho-mosaics, point clouds, and models (terrain, 3D georeferenced) in an automated process. This complements the existing surveys – terrestrial separated from aerial. It uses low cost gear (small remotely controlled aircraft), thus presenting a much less expensive option to deliver accurate images (less than 1cm) in a short timeframe (minutes or hours). Using this method can increase situational awareness of an incident scene or document areas during or after an incident.

Due to technology innovation of drones and sensors, solutions emerge where simultaneous localisation and mapping (SLAM)[20] solutions for outdoor applications make such accurate positioning over longer distances feasible for emergency services staff. In most cases, commercial off-the-shelf drones and sensors are employed.

Table 4: Aerial image examples

Drone-based cameras	**Drone-based imagery (ortho-mosaics, 3D meshes …)**
Flight Height: 30m Ground resolution <1 cm	Processing, Photogrammetry, LiDAR … Provisioning in minutes, hours
	
Amtrak disaster, Vermont USA 2015 *http://uavsurveys.plsurvey.com*	3D GIS imagery provisioning with drones *http://www.esri.com/products/drone2map*

3.1.4 | 3D CITY MODELS & 3D VISUALISATION

3D visualisation and localisation, especially of urban areas with 3D city models, is a valuable contribution for emergency services. INSPIRE and the Open Geospacial Consortium have taken up requirements[21] of different domains and provided the City Geography Markup Language (CityGML)[22] as a concept for the modelling and exchange of 3D city and landscape models. It ensures interoperability and simplifies the exchange of datasets and the design of interfaces.

CityGML consists of a general-purpose information model which contains complex and geo-referenced 3D vector data along with the semantics and in addition to geometry and graphics information. An extension mechanism for data enrichment is available to ensure semantic

[20] *https://en.wikipedia.org/wiki/Simultaneous_localization_and_mapping*
[21] In a broader sense 3D city models may also comprise 2.5D data sets (visual perception of a 3D perception) like a digital elevation model (DEM)
[22] *http://www.sig3d.org*; *http://www.opengeospatial.org/standards/citygml*

interoperability. Meanwhile various large-scale 3D city models are available, and several commercial vendors offer comprehensive 3D acquisition and modelling services.

In parallel, the adoption of building information modelling (BIM) in EU member states is promising[23]. Physical and functional characteristics of places are generated, e.g. buildings, or physical infrastructures, such as water, refuse, electricity, gas, communication utilities, roads, bridges, ports, tunnels. Once this effort matures, emergency services will be able to utilise such building information models, for example for 3D indoor information.

Figure 7: 3D Model, City of Munich

These interoperability-driven activities are challenged by web-based applications, where mobile devices require simplified data structures with lightweight formats (e.g. HTML5, WebGL[24]) to reduce bandwidth requirements and improve response times.

Augmented/virtual reality (VR) technologies with VR glasses and game controllers offer an encouraging opportunity for the 3D world. Virtual reality allows users in the command room to explore a place with a virtual photorealistic view using special glasses. Although the geo-industry is in the early development stage, the realistic possibilities of presentation could provide an even better imagination of the incident site. This may include walk-through animations, add analysis capabilities like potential security threats for crisis planning purposes, and most importantly, provide interaction (with gestures) in a real-time environment. Overall, emergency services should recognise that the importance of 3D visualisation continues to grow. The central aspect in 3D visualisation is the topic of platform-independent solutions. Therefore, emergency services should first strive to link 2D and 3D representations of their service area.

[23] *https://en.wikipedia.org/wiki/Building_information_modeling#Europe*
[24] *https://www.khronos.org/webgl/*

3.1.5 | SPATIAL DATA SETS AND METADATA[25]

The distributed responsibility and nature of geodata, with overlaps and different descriptions, requires the provisioning of interoperable geodata.

Therefore, metadata are used and are increasingly standardised to describe spatial data sets and spatial data services. This makes it possible to discover, make inventory of and use them. With metadata, the spatial data sets become an identifiably collection of spatial data, which can be processed and are the key ingredient for spatial interoperability.

3.1.6 | GEOINFORMATION SOURCES

The key sources for geodata are the national Cadastral and Surveying Authorities and commercial vendors where products like topographic maps and elevation data, aerial view products, navigation data or real estate cadastre (partially downloadable depending on resolution) are available. Further data portals, e.g. with satellite images, terrain models or digital elevation data in different solutions are available as well.

Table 5: Data portals - examples

Portal	Offer	Region	Price	Link
Copernicus Emergency Management Service	Rapid Mapping, Risk and Recovery; activation by "authorized users" (EU member states).	World	Free of charge	*https://emergency.copernicus.eu/*; access via the 24/7/365 Emergency Response Coordination Centre (ERCC) at the Directorate- General for Humanitarian Aid and Civil Protection (DG ECHO).
European Environment Agency	305 European cities (>100k inhabitants); update for appr. 700 cities (European cities >50k inhabitants)	Cities	Free of charge	*https://www.eea.europa.eu/data-and-maps/data/copernicus-land-monitoring-service-urban-atlas* Preliminary download (2012 data): *http://land.copernicus.eu/local/urban-atlas/urban-atlas-2012*
EarthExplorer	Landsat, OrbView-3, Sentinel-2 SRTM	World	Free of charge	*http://earthexplorer.usgs.gov/*
Digitalglobe ImageFinder	WorkdView, GeoEye-1, Quickbird, IKONOS	World	€	*https://browse.digitalglobe.com/imagefinder*

[25] *http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32007L0002&rid=1*

Reverb|ECHO	Landsat, SRTM, ASTER MODIS	World	Free of charge	*https://search.earthdata.nasa.gov/search*
Sentinel Data Hub	Sentinel-1, Sentinel-2	World	Free of charge	*https://scihub.copernicus.eu/*
National Cadastral and Surveying Authorities	Comprehensive map product offerings (analog, digital, on-line)	Country, State, Region	€ partial	Example Germany: *http://www.geodatenzentrum.de/geodaten/gdz_rahmen.gdz_div?gdz_spr=eng&gdz_user_id=0*
INSPIRE Geoportal	Spatial data sets and spatial data services, to view spatial data sets from the EU Member States	EU	Free of charge	*https://inspire-geoportal.ec.europa.eu/*
OpenStreet Map (OSM)	Free editable maps of the world (scale up to 1: 10.000)	World	Free of charge	*www.openstreetmap.org* Vector data: *https://www.geofabrik.de/en/data/download.html*
European Environment Agency	305 European cities (>100k inhabitants); update for appr. 700 cities (European cities >50k inhabitants)	Cities	Free of charge	*https://www.eea.europa.eu/data-and-maps/data/copernicus-land-monitoring-service-urban-atlas* Preliminary download (2012 data): *http://land.copernicus.eu/local/urban-atlas/urban-atlas-2012*
ESRI	Living Atlas of the World	World	€	*https://livingatlas.arcgis.com/en/*

Online access

Online access of spatial information has become a standard functionality based on common technical standards via web map services (WMS)[26] and internet protocols (http). WMS are synonymous with standard web interfaces for obtaining spatial data (maps, aerial photographs, etc.) from distributed geospatial databases to complement the own spatial database. The OGC (Open Geospatial Consortium) has defined a set of standard interfaces which are broadly used in various industries globally. Predominantly, the WMS, the web feature service (WFS), and the web coverage service (WCS) are some of the main standards.

[26] *www.opengeospatial.org*

* A **WMS** is a standard web (http) interface for obtaining spatial data (maps, aerial photographs, etc.) from distributed geospatial databases. With WMS, remote GIS databases can be accessed and the possibility of incorporating current geospatial data directly into the GIS of a PSAP is possible.

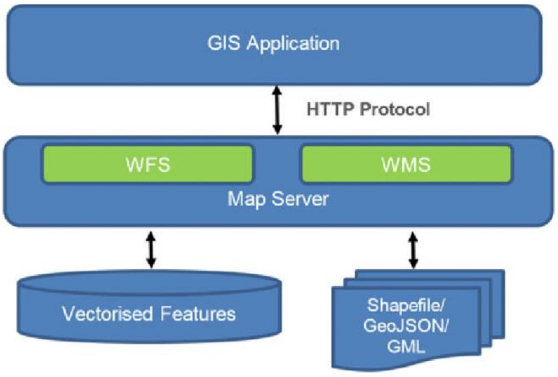


Figure 8: Illustration of web services

* **The WFS** offers access to geographic information at the feature property level. As opposed to WMS, where only images are submitted, the WFS provides property information e.g. a "lake" is described as lake including its polygon which can be spatially analysed.
* **Gazetteer Service (GS)**. In many situations, geographic names provide one of the most important keys for referencing and accessing a variety of other information. GeoNames databases, called Gazetteers, are an information resource for representing places, groups of people and cultures. The GS is a specialisation of the WFS which allows clients to search and retrieve elements of a georeferenced vocabulary of well-known place-names. Metadata are being used for platform-neutral access via an open web standard.
* **The WCS** defines the retrieval of multi-dimensional coverage data over the internet (space/time-varying phenomena). For instance, satellite images may contain varying degrees of light pollution, or coverages determine 1D sensor time series, or 3D X/Y/t image time series etc.

Usually, a combination of different GIS services is deployed to handle such datasets. As PSAPs must cope with mission critical requirements, often the web services implementations are optimised to meet the performance requirements in the call collection and dispatch processes. A local caching mechanism makes sure that the geodata are available even if the remote source is temporarily unavailable or access times are too long. Also, further geodata processing is executed to cut larger map images into smaller images to optimise transmission times.

Literally thousands of OGC web services are offering hundreds of thousands of maps and datasets, partially free-of-charge. The key ingredient in these searches is the OGC Catalog Services – Web (CSW) Interface Standard. These services provide the ability to publish and search metadata for data, services, and information objects to discover registered information resources: the prerequisite for spatial interoperability. Further search considering 1300+ WMS's and then some WFS, WCS, Sensor Observation Services (SOS) to query real-time sensor data, and CSW can be conducted[27]. In addition, the national Cadastral and Surveying Agencies provide the online base data for PSAPs.

It must be considered that in cross border/jurisdiction activities, for example when an emergency caller is identified beyond the jurisdiction, the incident location can only be pinpointed with the help of additional geodata from this area.

Additional sources are available for incident specific geodata requirements, for example missing persons, terror attacks or larger scale natural disasters. Public agencies in EU member states frequently offer services which provide a 24/7 service for the rapid acquisition, processing, and analysis of satellite data in conjunction with natural and environmental disasters. These services are often employed with worldwide humanitarian relief activities and for civil security purposes. Private companies also offer similar services for complex or long-lasting image processing, continuous monitoring of geographical areas, quality measures and special purpose analysis.

3.2 | GEODATA PROVISIONING

There is no general rule to describe what geodata PSAPs usually require. It depends on the duties and responsibilities, as well as on the topographic situation in the PSAP service area. In case of mountainous situations, more emphasis is probably on detailed scales and elevation models, whereas urban areas require a more detailed view on streets and buildings with appropriate resolutions.

Increasingly 3D-city models are being introduced to cope with the third dimension, and in some regions, indoor building maps such as floorplans or 3D models of interior spaces are used to provide understanding and awareness of the layout of critical infrastructure such as universities, corporate campuses, and industrial facilities.

Geodata, like an incident location or the area of a venue or service area, have direct relevance for incidents. The GIS is utilised for the visualisation of geodata kept in the Computer Aided Dispatch. GIS integration creates additional value in providing both the dispatchers and field personnel with situational awareness. Most CADs have integrated features such as caller location identification, mapping of resources, mapping of streets and important objects, best route calculation for first responders, maintenance of the attribute files of addresses, possibility of calling the vehicles via radio by a click on the map, among others.

[27] *http://gptogc.esri.com/geoportal/rest/find/document?searchText=WMS&start=1&max=10&f=searchpage*

The table below summarises typical geodata to exemplify the broad geodata foundation in PSAPs.

Table 6: Geodata examples in PSAPS

Base Data	Format / scale / system
Digital topographic map	Raster (main scales: 1:500.000, 1:200.000, 1:100.000, 1:50.000, 1:25.000, 1:10.000, 1:5.000) and usually combined with cadastral information like street names, geo-referenced buildings
Vector Data	Vector (possible acquisition scales: 1:500 000, 1:200.000, 1:100.000, 1:50.000, 1:25.000, 1:10.000, 1:5.000)
Digital cadastral map	Raster data
Orthoimages	Raster data
Cadastral information e.g. address data, streets, cities, post-codes	Vector (ex. 1:1.000, building coordinates as text-file)
Digital Contour Model	Raster data
Digital Terrain Model	Raster grid or vector base data (including attributes like street name, road width, or object groups like traffic, water) for spatial analysis
3D City Model (emerging)	Heterogeneous set of 2D raster, 2D vector-based data, 3D models and thematic datasets
Thematic Data	
Public rail network	Predominantly vector data
Waterways and shipping	
Motorway network	
Utilities e.g. pipeline-networks, powerlines	
Jurisdictive borders, police, fire, hospital stations, PSAP service areas …	

Emergency Services related data	
Base database updates e.g. new crossings, streets, buildings, temporal blockings	Depending on the deployment model, Geodata are managed both in the GIS and in the computer aided dispatch (CAD) application.
Points of interest (PoI)	
Building plans	The data representation is frequently derived from the database architecture of the application and the availability of the source information. For instance, building plans might only exist as images.
Service-related data, e.g. building access codes, safety information, risks and hazards, historic data	
Events and venues (time and location/ area dependent)	
Incident related data	
Incident and response team/ asset locations	
Tactical information e.g. operations zones, risk zones …	
Dispatch proposals, route calculations	

Despite these application requirements, emergency services must always find the good balance between costs and accuracy of geoinformation.

Time & update cycles

The European Location Framework (ELF) study[28] revealed update frequencies of topographic data in 2012. It reported that about 50% of the countries in scale 1:50 000 update data in less-than 2-4 years, and in 95% of countries in less than 5-10 years. Meanwhile, the update cycle of official sources like ordnance survey offices are between 0,5-3 years. However, one can assume that for certain data that are costly to produce, for example aerial images/ topographic maps, the timeframe will not significantly drop below 3 years from the time the image was taken until the final product is published.

[28] *www.elfproject.eu/sites/default/files/ELF%20White%20Paper.pdf*

Consequently, emergency services operations must continuously improve data maintenance processes and workflows to update data to ensure a close to reality data base. This may include new streets, crossings, addresses, buildings, and PoI. Open source information has reached a fair level of quality. Increasingly, additional sources have to be considered to improve interoperability between agencies and jurisdictions, for instance for cross-boundary missions or ad-hoc requirements to provide almost real-time 3D georeferenced images for defined emergencies or disasters with short-term (minutes – hours) update cycles.

Therefore, geoinformation skills are necessary for efficient discovery and provisioning per service delivery/accuracy requirements in the mission critical processes.

Cost

Prices for geoinformation have large differences in EU countries, but it can be assumed that price levels continue to decrease. The costs are basically driven by resolution, and how up-to-date data are. The better resolution and more up-to-date data, the more it costs.

Table 7: Geodata cost estimations (random examples)

Map/ Sensor	**Resolution**	**Cost estimation**
Digital Terrain Model	1m / 25m	80€ / 5€ per km^2
3D Buildings	Level of Detail 2	0,65 EUR/building
Pléiades Sensor	24h-Service	56€/km^2 (minimum 100km^2)
Aerial Image Generation	3cm	50k€ per mission

Data accuracy

PSAPs require position accurate data. Therefore, predominantly digital topographic models or landscape models (which are directly derived from survey data or photogrammetry) should be used as no generalisation steps during data processing took place. Cadastral and Surveying Authorities or private geodata companies - e.g. for car navigation systems - are the preferred sources.

It should be noted that the map scale significantly influences data accuracy. The smaller the map scale, the less space there is for the visualisation of an object. If such data are derived from generalised maps, it is usually unknown which guidelines were applied for objects, classification or aggregation. Therefore, emergency services should strive for different scales of an area to mediate such data accuracy influences.

3.3 | GEODATA MAINTENANCE

The previous sections indicated the need for robust geoinformation maintenance which ensures that data are updated, or existing data are replaced to reflect changes in the world or in the underlying datasets. Secure, easy access and the efficient use of geographic data must be facilitated for emergency services operations. Essentially, GIS administrators need to be educated and tools & instruments must be available for further analysis and quality improvement. Familiarity with existing geo guidelines and standards is key.

The main **maintenance** tasks are:

- the review of new geodata
- the submission of new geodata, including data transformation due to different coordinated systems, and the aggregation and compression of data to meet performance requirements
- to ensure cross-border consistency and accuracy of the data, including conformance testing
- to sustain metadata for interoperability and quality measures
- to ensure consistency between spatial information in location databases (such as addresses of wireline telephone subscribers), the CAD, and in the GIS (data clean-up)

Geodata **development** comprises:

- Definition of data models and schemas of the geodatabase. For instance, for ad-hoc 2D/3D georeferenced images provided by drones, the application of 3D-city models etc. in addition to simple yet fundamental features like road centrelines, address points, and service boundaries
- Provisioning of additional layers for the convenience of the dispatchers in the control room and the introduction of new attributes for tactical analysis
- Processing and combination of new or revised datasets

Quality management

This is the core process in geodata management where the quality of geodata is measured and ensured. As quality is assessed, any errors that are identified must be conveyed to the original creators or the stewards of the data, so that problems can be remediated and data re-evaluated for quality. This cyclical maintenance workflow is key to managing the lifecycle of GIS data. In addition, mechanisms must be available to collect feedback on data quality from the geodata consumers as basis for the identification of errors and improvement areas.

Security and data policies

It is obvious that the utilization of geodata in a distributed environment creates security concerns. Usually, the on-line access to remote sources from secure PSAP infrastructure is prohibited. Vice versa, the access from mobile devices to central geodata requires secure networks. Therefore, a thorough network architecture must be implemented which copes with these requirements. Besides, license agreements to comply with legal prerequisites must be met, as well.

3.4 | GEODATA SHARING AND DISTRIBUTION

The main geodata consumer in the PSAP is the CAD, which frequently itself embeds the GIS including the spatial database. Dispatchers are then in the position to visualise more in-depth spatial information on a specific area or location by overlaying multiple datasets and correlating them with each other.

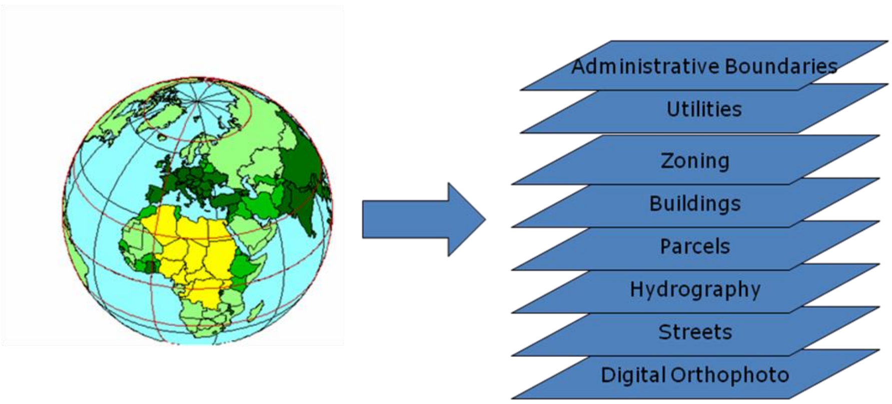


Figure 9 : Geodata layers

The geodata is organised by *layers*, with each layer representing a common feature.

Layers are integrated using explicit locations on the earth's surface, thus the geographic location is the organising principle.

Layers are comprised of **spatial** data which describes location (where) and **attributes** specifying what, how much, when.

Layers may be represented in vector format as points and lines, and in raster (or image) format as pixels. Raster layers can be combined with vector layers. The order in which layers are structured is very important to properly display the result.

All geographic data has 4 properties:

- **Projection:** the method by which the curved 3-D surface of the earth is represented by X,Y coordinates on a 2-D flat map/screen. Distortion is inevitable.
- **Scale:** the ratio of distance on a map to the equivalent distance on the ground. In theory, GIS is scale independent but in practice there is an implicit range of scales for data output.
- **Accuracy:** how well does the database information match the real world? *Positional*: how close are features to their real world location? *Consistency*: do feature characteristics in the database match those in real world? *Completeness*: are all real-world instances of features present in the database?
- **Resolution:** the size of the smallest feature able to be recognised. For raster data, it is the *pixel* size.

Two online examples for geodata combining thematic data will be shared. The first example exemplifies 112 PSAP locations, contact information and service areas in Bavaria, Germany, where raster, vector and thematic data are joined. One can imagine that future location-based routing services for emergency calls can easily utilise this dataset.

Figure 10: Bavarian PSAPs, service areas [29]

[29] Example from the Bavarian Atlas (LDBV Bavaria): *https://goo.gl/1lMkUE*

The second example provides online spatial information for communities and cities, which assume responsibility for coordination of disaster response.

GeoKAT[30] as a portal for counties and communities provides access to centrally maintained maps and thematic databases to answer typical questions of crisis management teams and incident leaders:

- Are there schools, kindergartens, and nursing homes in the endangered areas that need to be evacuated?
- What age structures do the affected residents have?
- Where are gyms, trucks, camp beds, or sandbags located?
- Which area is impacted by an impending flood?

To be flexible, the geodata may be stored on-site on devices (laptops and others), as well. A synchronisation mechanism keeps the data constantly updated and provides data offline in case the communication connection is lost.

3.4.1 | DEPLOYMENT ARCHITECTURES

Geodata management infrastructures are being deployed more and more as services. These services act as a unit of abstraction for providing, changing and viewing spatial information. PSAP operators are then able to arrange the most efficient solution for their specific needs. This applies to a single PSAP deployment, to distributed command centres, or to multi-agency deployments.

Such deployment options allow one to:

- decouple GIS management from incident management, protecting sensitive information in line with IT security and data privacy requirements.
- implement a secure online access to obtain and cache spatial information from remote databases. The geodata provisioning via standardised interfaces, as well as for various devices of emergency services staff, is possible from this site, as internet access is de-coupled from the sensitive command centre core infrastructure.
- setup a hosting/hybrid service in conjunction with partners. For instance, specialised geodata companies maintain the geodata on behalf of the government/emergency services or provide stand-by capacities in case of short-term geodata processing tasks.
- deploy new services, e.g. location-based call routing services, which utilise geodata as core feature.
- improve collaboration across agencies as access to spatial information can be granted more easily.
- utilise standard GIS products and services, which eases compliance with geodata standards and also drives market and competition in the public safety niche.

30 *www.stmi.bayern.de/med/pressemitteilungen/pressearchiv/2016/100b/index.php*

As for any centrally hosted service, the same advantages apply to centralised geodata management services:

- Consistent Geodatabase maintenance processes
- Used on demand
- Subscription-based licensing
- Reduced operating expenditures (OPEX)
- Access on demand and available everywhere
- IT-Security compliant and multi-party GIS expert involvement

3.4.2 | INTEROPERABILITY

In today's emergency services environment, PSAPs generally build their own datasets, an archipelago of spatial information with little uniformity between systems. The direct reflex to this observation leads to the demand for wide-ranging interoperability of geo-spatial information to improve interaction between the emergency services organisations in Europe.

A brief excursion into INSPIRE emphasises the value of the orchestration of distributed spatial information and exposes the advantages and limitations of this EU-wide initiative from an emergency services perspective. INSPIRE enables the sharing[31] of environmental spatial information among public sector organisations and facilitates public access to spatial information across Europe. The benefits for emergency service organisations are at least two-fold:

1. Base data (maps, images …) and thematic databases provided by the Cadastral and Surveying Agencies increasingly comply with interoperable standards, which enable PSAPs to acquire these datasets easier and with minimised integration effort.
2. INSPIRE significantly leverages the online provisioning of geodata, which results in shorter provisioning cycles. Emergency services increase their perception of trusted and official spatial information sources and become familiar with the distributed spatial databases.

The full set of spatial data required for emergency services operations will not be covered, though, as standardised data models considering semantics and ontologies for incidents, resource types i.e. for incident/emergency/disaster related geodata are not subject of INSPIRE. Emergency services organisations and industry are encouraged to establish a geospatial working group for emergency services organisations. An example is, DGIWG[32]: a geospatial standardisation working group for the defence organisations to leverage standardisation in conjunction with emerging data services and collaboration requirements.

[31] *http://inspire.ec.europa.eu/index.cfm/pageid/2*: Interoperability: Possibility to combine spatial data and services from different sources across the European Community in a consistent way without involving specific efforts of humans or machines. It provides access to spatial data sets through network services, typically via Internet and inherently comprises the harmonization of existing data or the transformation via services for further publication.
[32] *www.dgiwg.org*

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4 | CONCLUSIONS

Without any doubt, spatial information has become a mission-critical attribute of today's emergency services operations. PSAPs are encouraged to accept that geodata is more than just a digitised map at the workplace. Situational awareness and operational needs require the composition of distributed spatial information online, which enables emergency services to complement existing geodata with additional data. INSPIRE is understood as one of the key enablers to assist ordnance and survey authorities in the EU member states to merge towards standardised and interoperable base datasets.

In combination with the advancement of mobile technologies, location intelligence no longer resides in the control room only. Geodata can be accessed from anywhere with almost any device, and emergency location/routing services may also utilise data services. In addition, location accuracy is improving outdoors due to improvements in satellite navigation systems (GNSS) and indoor location accuracy is improving due to advances in Wi-Fi and beacon-based positioning technology. Higher-accuracy caller locations, both outdoors and indoors, support the emergency services' mission of providing response more quickly. Call takers can locate callers faster, with less errors, and field responders can navigate to locations more accurately, even indoors. The multitude of positioning technologies will continue to grow and improve in the future, which will continue to improve response times and increase the importance and need for higher accuracy geodata.

Aerial imaging for rapid orthophoto processing with RPAS is an increasing application. Broader technology penetration with smart algorithms and sensors in conjunction with the driving consumer market will significantly reduce so far expensive geodata acquisition and processing effort of emergency services organisations. Geodata, processed "on-the-fly", improve situational awareness and decision support. For example, for special response teams in terror attacks, weather related disasters, field staff safety and support.

As mature and worldwide-accepted technical standards for geospatial interfaces are available for years, it is up to emergency services and governments to establish a secure network access, in line with IT security and data privacy regulations and guidelines. Intermediary steps with a decoupled staging area can help bridge security concerns.

Accordingly, the transformation of PSAP operations from applications management towards a service-oriented spatial data service delivery and service management organisation should be considered in organisational planning and future technical PSAP architecture discussions.

5 | EENA RECOMMENDATIONS

Stakeholders	Actions
European Authorities	Continuous support of the standardisation process within ISO TC211 and CEN TC287.
National Government	Continuous support of the standardisation process within ISO TC211 and CEN TC287. Setup bi-mutual agreements between states/countries to exchange geodata for emergency services purposes. Establish a geospatial working group for emergency services organisations to drive standardisation in conjunction with interoperability and collaboration.
National / Regional Authorities	Complete assessment of current mapping capabilities, including datasets, maintenance processes, standards, and workflow policies. Defining the cooperation policies between different institutions / GIS users; data access principles; conversion rules. Building the relevant databases themselves, taking the required actions to ensure that geodata remains accurate and well-maintained, that updates to geodata are made in a timely fashion and made available as quickly as possible, and that spatial information are available and accessible when they're needed. Strive for online access with data security and data privacy guidelines, as significant EU-wide efforts are spent on interoperable geoinfrastructures.
Emergency services	Geodata for emergency response represent a significant investment. Spatial information must be maintained, and stringent quality assurance and quality control systems must be established to avoid gaps and inconsistencies. Improved location information (emergency callers, staff, and assets) leverages the need for increased base map data quality and accuracy. Consider ad-hoc aerial imagery provisioning for improved situational awareness and field staff safety. Define geodata cooperation needs with other (adjacent) agencies. Establish pilot projects for 3D models to develop operational requirements.

National telecommunication regulator / Network operators	Provide legal and technical frameworks for call routing and PSAP selection based on already available spatial information. Complete and maintain spatial database of their resources (transition networks, cellular networks, fixed telecommunication network).
Industry	Maintain cooperation and support interoperability through Open Geospatial Consortium and relevant standardisation/ interoperability initiatives.

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6 | TERMS & ACRONYMS

All definitions of terms and acronyms used in this document are listed below in alphabetical order.

Acronym	Description
AML	Advanced Mobile Location
BIM	Building Information Modelling
CAD	Computer Aided Dispatch
CEN	European Committee for Standardization - Comité Européen de Normalisation
CityGML	City Geography Markup Language
CSW	OGC Catalog Services - Web
DEM	Digital Elevation Model
DXF	Contour elevation plots in AutoCAD DXF format (Autodesk)
ELF	European Location Framework
ELISE	European location interoperability solutions for e-government, a sub-activity of ISA
EMT	Emergency Medical Technician
GeoTIFF	TIFF (Tagged Image File Format) variant enriched with GIS relevant metadata
GIS	Geographical Information System
GNSS	Global Navigation Satellite System
GS	Gazetteer Service
INSPIRE	Infrastructure for spatial information in Europe
ISA	Interoperability solutions for public administrations, businesses, and citizens
ISO	International Standardization Organization
JPEG	Joint Photographic Experts Group, lossy compression method of digital images
LoD	Level of Detail
NG112	Next Generation 112
OGC	Open Geospatial Consortium[33]
OPEX	Operational expenditure
Ortho-imagery	Aerial photograph/image geometrically corrected ("ortho-rectified") so the scale is uniform.
PNG	Portable Network Graphics as a raster graphics file format for lossless data compression

[33] *www.opengeospatial.org*

PSAP	Public Safety Answering Point
PSBD	Public Safety Bomb Disposal
RPAS	Remotely Piloted Aircraft System, see also UAS
SAR	Search and Rescue
Shapefile	vector data GIS format (ESRI)
SLAM	Simultaneous localization and mapping[34] problem of constructing/ updating a map of an unknown environment while simultaneously keeping track of an agent's location within it.
SOS	Sensor Observation Service
TC	Technical Committee
UAS	Unmanned Aircraft System, see also RPAS
UVS	Unmanned Vehicle System
VR	Virtual Reality
WebGL	Web Graphics Library
WCS	web coverage service, OGC standard
WFS	web feature service, OGC standard
WGS84	World Geodetic System with its latest revision in 1984
WMS	web map service, OGC standard

[34] *https://en.wikipedia.org/wiki/Simultaneous_localization_and_mapping*