Chapter 3
Establishing Common Ground Through INSPIRE: The Legally-Driven European Spatial Data Infrastructure

Vlado Cetl, Robert Tomas, Alexander Kotsev, Vanda Nunes de Lima, Robin S. Smith and Markus Jobst

Abstract Back in the 1990s, there were several barriers for accessing and using the spatial data and information necessary for environmental management and policy making in Europe. These included different data policies, encodings, formats and semantics, to name a few. Data was collected for, and applied to, domain specific use cases and comprehensive standards did not exist, all impacting on the re-usability of such public sector data. To release the potential of spatial data held by public authorities and improve evidence-based environmental policy making, action was needed at all levels (Local, Regional, National, European) to introduce more effective data and information management and to make data available for citizens' interest. The INSPIRE Directive, the Infrastructure for Spatial Information in Europe, directly addresses this set of problems. The Directive came into force on 15 May 2007, with full implementation in every EU Member State required by 2021. It combines both, a legal and a technical framework for the EU Member States, to make relevant spatial data accessible and reused. Specifically, this has meant making data discoverable and interoperable through a common set of standards, data models and Internet services. The Directive's data scope covers 34 themes of cross-sector relevance as a decentralised infrastructure where data remains at the place it can be best maintained. A great deal of experience has been gained by public administrations through its implementation. Due to its complexity and wide scope, this is taking place in a stepwise manner, with benefits already emerging as important deadlines approached. Efficient and effective coordination are following the participatory approach established in its design. It is timely to reflect on 10 years of progress of the "cultural change" which the European Spatial Data Infrastructure represents. We therefore, consider the lessons INSPIRE is

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offering for those interested in joined-up and federated approaches to geospatial data-sharing and semantic interoperability across borders and sectors. The approach itself is evolving through this experience.

Keywords European spatial data infrastructure · INSPIRE · Data interoperability Service-oriented architecture

3.1 Introduction: The Need for a European Spatial Data Infrastructure

Climate change, natural disasters such as floods, air pollution or any environmental phenomenon do not stop at political borders and exercise complex, inter-related effects on society (Masser 2005). To take effective preventative measures, the mitigation of impacts occurring from local to global levels or to support sustainable economic, social and environmental development, information and georeferenced data must be shared across organisations and borders (Rajabifard et al. 2002). Such activities involve stakeholders from different contexts, including public administrations, businesses, research bodies and citizens and their combined efforts lead to the results that we see in practice.

Looking back twenty years to the 1990s, the accessibility and online sharing of public sector data were minimal. Finding content was very difficult. Documentation was poor or missing and data were kept in incompatible formats. It was difficult and time consuming to combine datasets from different sources (Craglia 2010). Data-sharing was also hampered by cultural and institutional barriers, including closed or non-existent data policies. At the same time, European Union (EU) policies needed data throughout the whole policy cycle (for formulation, assessment and monitoring). This situation needed to take into account the cultural, technical and political diversity of situations across Europe's regions.

In order to overcome these challenges, strong coordination was needed between stakeholders at European and national levels. The most appealing solution for all was a pan-European Spatial Data Infrastructure (SDI), leveraging on existing national and regional data infrastructures. In particular, this was addressed on a political level through the establishment of a European framework directive, Infrastructure for Spatial Information in the European Community—INSPIRE (Directive 2007/2/EC, in the following referred to as the "Directive").

Within this chapter, exactly ten years after its adoption, we take the opportunity to reflect on the development and implementation of the Directive. We also highlight the benefits it is bringing through the establishment of both, its legal and technical framework. Structurally, the chapter is organised in four sections. An introductory section, defining the context (Sect. 3.1) is followed by an extensive overview of the design and implementation of the Directive (Sect. 3.2). It continues with a discussion on the selected benefits for society (Sect. 3.3). Section 3.4

concludes with a discussion on the recognised challenges and an outlook for the future evolution of the infrastructure.

3.2 INSPIRE: An Overview

As with most SDIs, technical framework needs to be accompanied by a set of organisational rules and agreements. In the case of INSPIRE the technical framework was strengthened by political framework through European law. The setting-up of both was itself a multi-disciplinary, inclusive and transparent process, which unique experience is part of best practices. Those best practices have to be considered when such transversal innovation is in the act. This section gives an overview of how the European SDI has been developed and implemented.

3.2.1 Developing the Framework—Legal and Technological Setting

The legal framework has been set by the Directive (2007/2/EC) and interdependent legal acts, which are called implementing rules, in the form of Commission regulations and decisions. By design, the infrastructure itself is built upon the SDIs established and operated by European Union member states that are then made compliant with the implementing rules, covering its core components: metadata, network services, interoperability of spatial datasets and services, data-sharing and monitoring and reporting (see Sect. 3.2.2), together with the obligation to establish a national coordination body.

As a Directive, the legal obligations did not come into force immediately but had to be transposed into national law. Its scope applies to spatial data held by, or on the behalf of, public administrations in performance of public tasks, with a focus on environmental policies or policies which have an impact on the environment. The Directive does not require a collection of new data, instead existing data should be transformed to fit agreed data models. The SDI is also developed and implemented in a decentralised and distributed manner, mainly following fundamental principles (European Commission 2007a, b):

- Data should be collected only once and kept where it can be maintained most effectively.
- It should be possible to combine seamless spatial information from different sources across Europe and share it with many users and applications.
- It should be possible for information collected at one level/scale to be shared with all other levels/scales; i.e. detailed for thorough investigations and general for strategic purposes.

- Geographic information needed for good governance at all levels should be readily and transparently available.
- Easy to find what geographic information is available, how it can be used to meet particular needs, and under which conditions it can be acquired and used.

More specifically, its thematic scope involves 34 data themes (Fig. 3.1), divided in three annexes of the Directive that reflect two main types of data: spatial reference data presented in annex I and partly in annex II in order to define a location reference that the remaining themes can then refer to.

Such a broad, cross-sector data infrastructure was not only intended to support European policies but also national policies and requirements at all levels of government. Benefits are likely to reach actors beyond the immediate scope, including businesses and citizens.

To guide implementation, these legal acts were supplemented with a detailed technical framework. This consisted of a set of technical guidelines and tools developed in a collaborative manner, and based on international standards (see Sect. 3.2.2).

The development of implementing rules and technical guidelines for all infrastructure components (metadata, services, data interoperability, monitoring and reporting) was an interactive process (Fig. 3.2) that included many stakeholders (Fig. 3.6).

3.2.2 *Infrastructure Components*

The implementing rules for metadata, the interoperability of data theme, the network services (that help to share the infrastructure's content online) and data

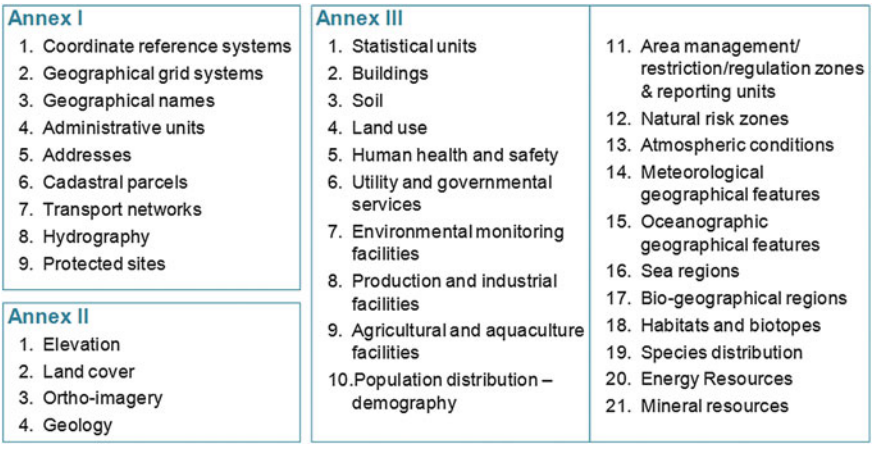

Fig. 3.1 INSPIRE themes, organised in three Annexes. *Source* INSPIRE Directive (2007/2/EC)

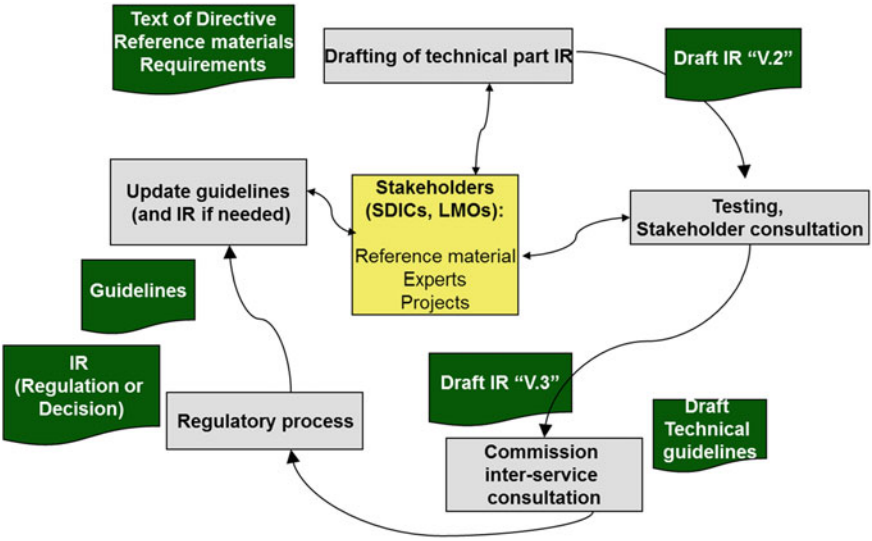

Fig. 3.2 Development cycle of implementing rules and technical guidelines. *Source* EC, Joint Research Centre

sharing are complemented by 'non-legally binding' technical guideline documents. These guidelines explain possible technical approaches for implementing the legal requirements and embed additional recommendations that may help in their implementation for a range of use cases.

3.2.2.1 Metadata

Member States ensure that metadata are created for the spatial data sets and services corresponding to one or more of the INSPIRE themes. Those metadata have to be kept up-to-date in accordance with the data and services (European Commission 2007a, b). INSPIRE metadata are based on the well-established EN ISO 19115 and EN ISO 19119 standards. Two sets of metadata elements are defined:

- discovery metadata,
- metadata elements for interoperability (sometimes also referred to as evaluation and use metadata).

In addition, some theme-specific requirements for the discovery metadata elements may occur. Those are described within the data specification of the related theme.

Metadata should be created and published through the network services in order to make the actual data discoverable. Data access is then established through view and download services which are documented in the metadata as well.

3.2.2.2 Data Specifications

In INSPIRE data specifications refer to predefined interoperability target specifications (Tóth et al. 2012). They contain agreed data models, based on a generic conceptual data model (European Commission 2013), common encoding rules, harmonised vocabularies, and registers (European Commission 2014). Together they form the key pillars of data and service interoperability (Fig. 3.3). They ensure coherence within the infrastructure, and promote the reuse of data and information according to the '*once-only*' principle (European Commission 2016a, b).

The methodology for the development of individual data specification followed a commonly agreed pattern based on the ISO 19131 standard (International Organization for Standardization 2010).

The resulting core data models for each theme are part of the legal provisions of the Directive. They represent a minimum set of spatial objects and their associated attributes that the communities of practice (domain experts in drafting teams) were able to agree on. They took also requirements gathered via a set of use cases into account. Nevertheless, core models are to be extended according to specific needs of a given domain, national use cases or applications that a user is confronted with.

The presence of controlled vocabularies is another essential pillar of interoperability. The spatial object characteristics (properties) are described by the commonly agreed semantics, which are expressed in the form of enumerations or code lists with precisely defined values and terms. All the semantics included in the legal text have been translated into 24 languages and are now accessible via the INSPIRE registry service (see Sect. 3.2.2.4). This central infrastructure component currently

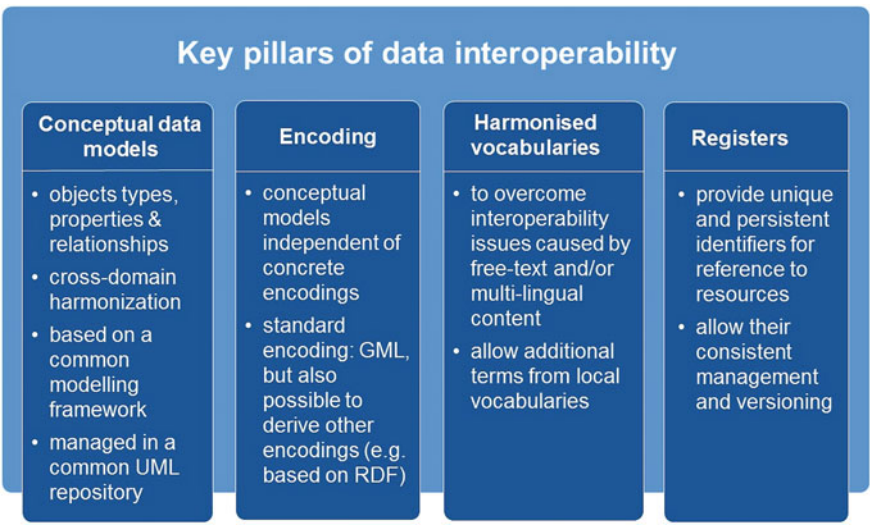

Fig. 3.3 Pillars of data interoperability in INSPIRE. *Source* EC, Joint Research Centre

contains seven different registers, including a code list register that further facilitates data and service interoperability.

Figure 3.4 illustrates how the real-world is modelled through consensus-based data specifications and an associated data model.

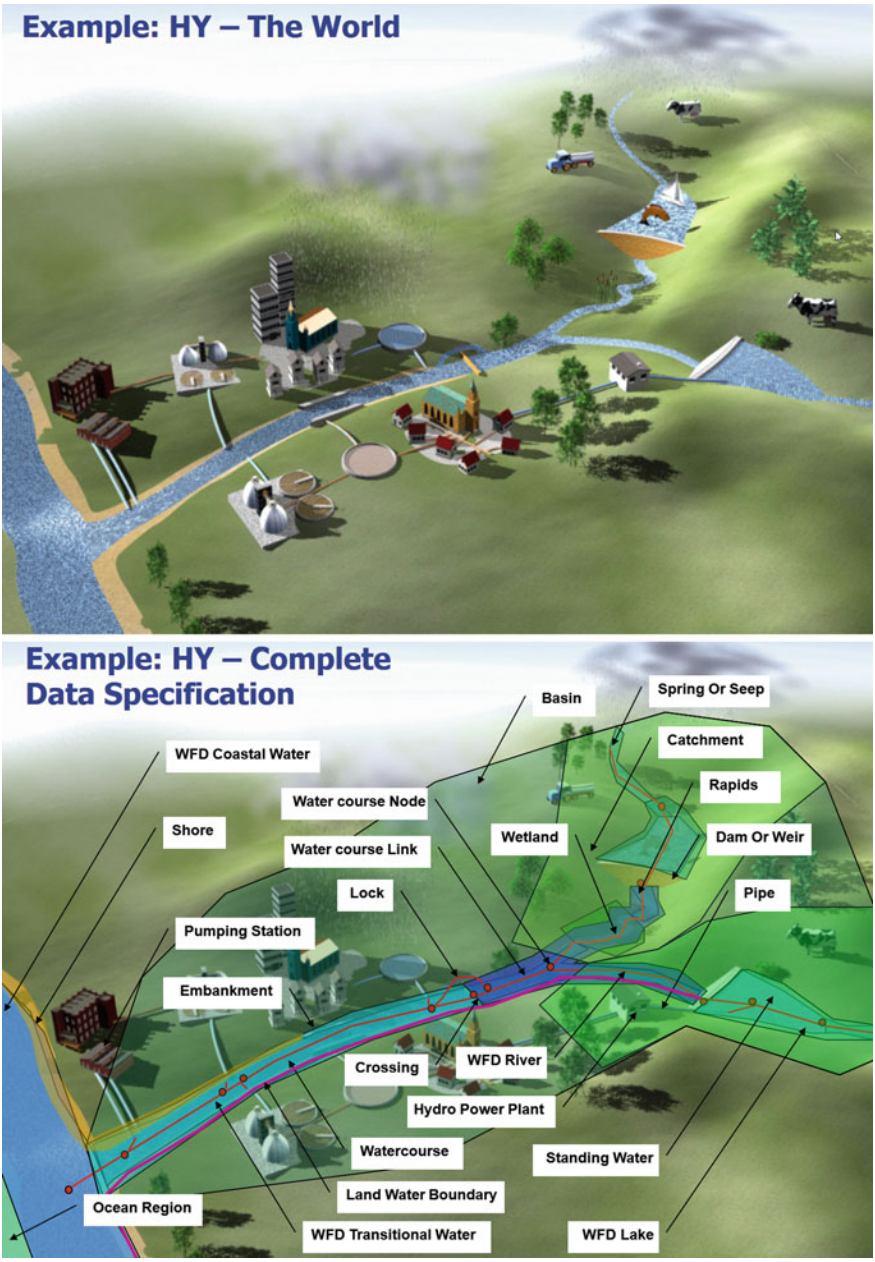

Fig. 3.4 Abstraction of the real world in INSPIRE. Example from the "Hydrography" data theme. *Source* EC, Joint Research Centre

3.2.2.3 Network Services

Data, functionality and metadata are shared through web-based services, referred to as Network Services (European Commission 2009), based on a Service-Oriented Architecture (SOA) approach (Fig. 3.5). These are based on well-established standards, mainly developed by the Open Geospatial Consortium (OGC). Non-legally binding technical guidance documents illustrate how data providers establish access to metadata for discovery services through catalogue service for the web (CSW). Similarly for View Services, the interactive visualisation of georeferenced content, involves guidance on Web Map Service (WMS) and Web Map Tile Service (WMTS). Download services also have guidelines that recommend the use of Atom, Web Feature Service (WFS), Web Coverage Service (WCS) and Sensor Observation Service (SOS), for appropriate types of data. There are also various transformation services defined, which can support coordinate and data transformations. In addition, there are generic services (registry and other spatial data services), that are implemented on a national as well as European level.

Deadlines for the establishment of network services precede those that address data harmonisation. Geospatial data is made available 'online first', thus unlocking it as is for further use (see Fig. 3.7).

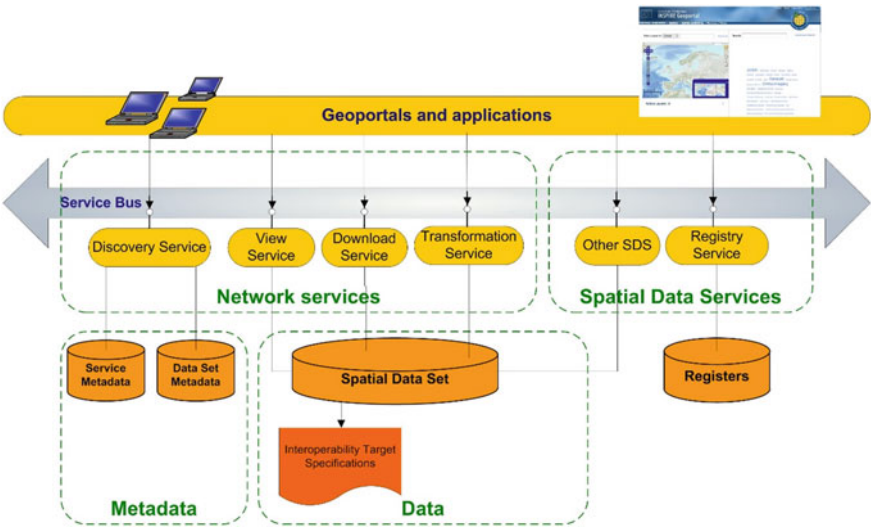

Fig. 3.5 Distributed service-oriented architecture of INSPIRE. *Source* EC, Joint Research Centre

3.2.2.4 Central Components

As shown in Fig. 3.5, several central components are illustrated that either establish interoperability on a pan-European scale or support the use of the infrastructure. Alongside national geoportals, the pan-European INSPIRE geoportal[1] serves as a central access point to data and services from organisations in the EU Member States and EFTA countries.[2] It enables not only cross-border data discovery, visualisation and use, but also metadata, data and service validation.

Another important central component of infrastructure is the INSPIRE Registry,[3] an online system to provide access to several centrally-managed registers. The content of these registers are based on the Directive, implementing rules and technical guidelines, especially for metadata and data and service interoperability. These registers facilitate semantic interoperability by offering common, persistent and clear descriptions of infrastructure items, referenced through unique identifiers. Furthermore, the content is neutral from a natural language point-of-view. Examples for such items include (i) data themes, (ii) code lists and (iii) application schemas. Registers provide a means for data providers to assign identifiers to items and their labels, definitions and descriptions (in different languages). Therefore it follows common reference material that uses controlled semantics. It can also be extended depending on the application or policy requirements.

3.2.2.5 Data-Sharing

Under the terms of INSPIRE Directive, each Member State shall adopt measures for the sharing of and enabling access to spatial data sets and services between its public authorities for the purposes of public tasks impacting the environment. It requires that such measures "preclude any restrictions likely to create practical obstacles" (European Commission 2010), occurring at the point of use, e.g. sharing of spatial data sets and services. The arrangements for sharing of spatial data sets and services shall be open to public authorities of other Member States and to the institutions and bodies of the European Union. They also "shall be open, on a reciprocal and equivalent basis, to bodies established by international agreements to which the Community and Member States are parties, for the tasks impacting the environment". These provisions are particularly important for supporting the European contribution to the global 2030 Agenda for sustainable development (United Nations 2015) and the United Nations Sustainable Development Goals.

Available guidance documents give examples of data and service sharing.[4] They include non-mandatory sample agreements which can be modified and adopted by

[1] http://inspire-geoportal.ec.europa.eu.

[2] Iceland, Lichtenstein, Norway and Switzerland.

[3] http://inspire.ec.europa.eu/registry.

[4] Guidelines and good practice documents on data sharing. http://inspire.ec.europa.eu/data-and-service-sharing/62.

public authorities. The proposed approach follows a general understanding to obtain a higher level of harmonisation with positive implications on national and European levels.

However, a number of organisational and legal challenges remain. There is still a diversity of license conditions between countries and in some cases even among national public authorities. At the same time the increasing convergence to 'open data' is an evident trend on European scale. It was recognised in the Member States reports on monitoring the implementation of INSPIRE within the last three years.[5] The evolution of this movement is fully in line with the principles of INSPIRE and its main requirement to make data accessible (see Sect. 3.2.1). Adopting this data policy approach is often a consequence of collaboration established between public administrations that decide to share the costs of implementing data services and interoperability requirements. At the same time, they have to agree on common sharing arrangements under their national Open Data policy agenda.

3.2.3 Main Actors and Stakeholder Engagement

Beyond these legal and technical aspects it was recognised that appropriate coordination mechanisms would be needed on multiple levels. Stakeholders were engaged from the outset, even before the Directive was published. The inclusiveness was important especially in the light of the decentralised architecture, where themes addressed data under the governance of different Member State ministries and at different levels of administration. The multi-disciplinarily nature of the domains, combined with the rapidly evolving ICT landscape, required the full and inclusive involvement of hundreds of stakeholders and experts from all across Europe (Fig. 3.6). Two groups of stakeholders were identified: Legally Mandated Organisations (LMOs) and Spatial Data Interest Community (SDIC). They had an active and fundamental role in proposing, developing and reviewing all technical aspects (Fig. 3.6). Member states were represented by the INSPIRE committee and appointed national contact points, who regularly provide information about implementation progress in their countries.

The breadth of activity in the Member States was also reflected by the European Commission bringing together different actors. Directorate General Environment is in the role of the policy master and the Joint Research Centre (JRC) as the technical coordinator. Eurostat and the European Environment Agency support with use-case specific developments.

Considering the large number of stakeholders involved on a voluntary basis, the development of the infrastructure and the engagement of stakeholders can be considered as a leading practice in policy and technical development.

Furthermore, after adoption of the legal frame, this spirit was sustained in the implementation and maintenance phases. A Commission Expert Group for the

[5] https://inspire.ec.europa.eu/Monitoring-and-Reporting/Monitoring-and-Reporting/69.

Fig. 3.6 INSPIRE stakeholder involvement 2007–2013. *Source* EC, Joint Research Centre

Maintenance and Implementation of INSPIRE (MIG)[6] is in place to agree a multi-annual work programme (MIF 2016) to address technical issues that need to be solved in a harmonised way for all Member States. Therefore it supports interoperability across borders, coherence between policies and the effectiveness of the results. Collaboration is also reflected in the development and sharing of reusable tools to facilitate implementation. The use of thematic platforms helps to share implementation experiences among implementers, developers and provide more information to citizens.

[6] http://inspire.ec.europa.eu/inspire-maintenance-and-implementation/.

3.2.4 *Implementation and Maintenance*

The deadline for Member States to transpose the Directive into their national legislation was 15 May 2009. The implementation process started immediately after, following an implementation roadmap that treats each component individually through a stepwise approach (Fig. 3.7).

The first important milestone was in December 2013, when Member States were obliged to provide their data as-is. This step established metadata and exposed data

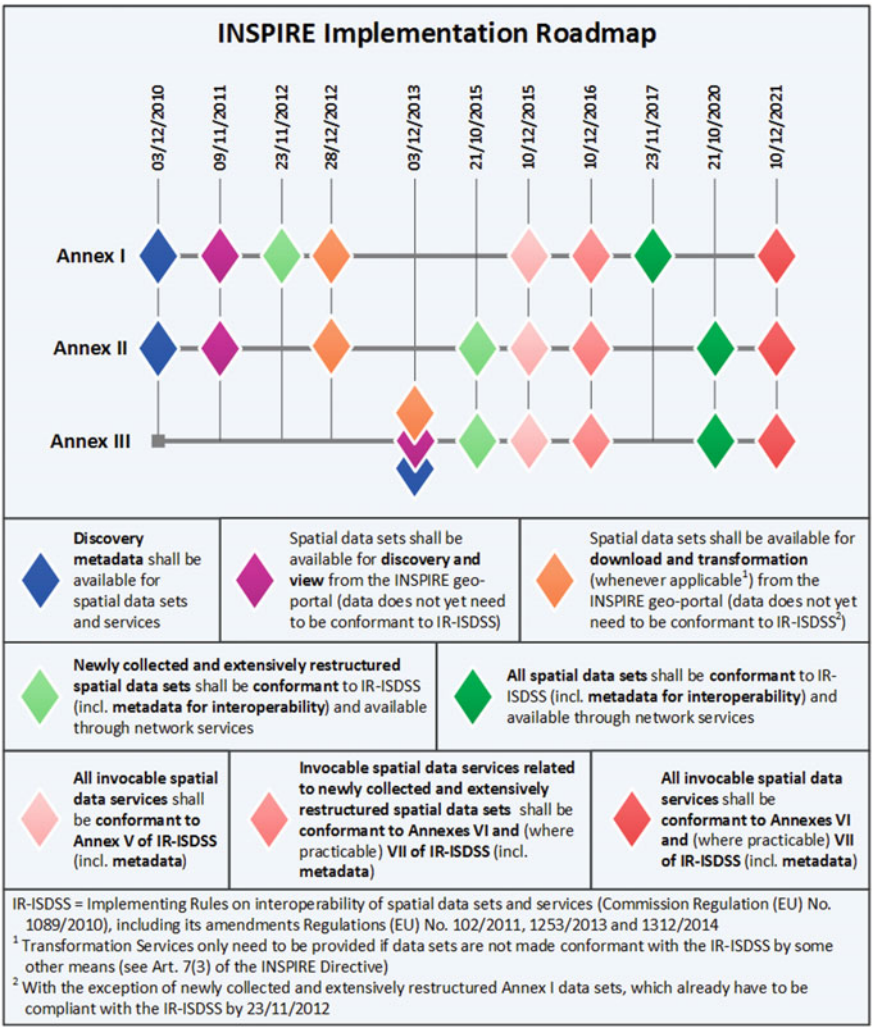

Fig. 3.7 INSPIRE implementation roadmap. *Source* EC, Joint Research Centre

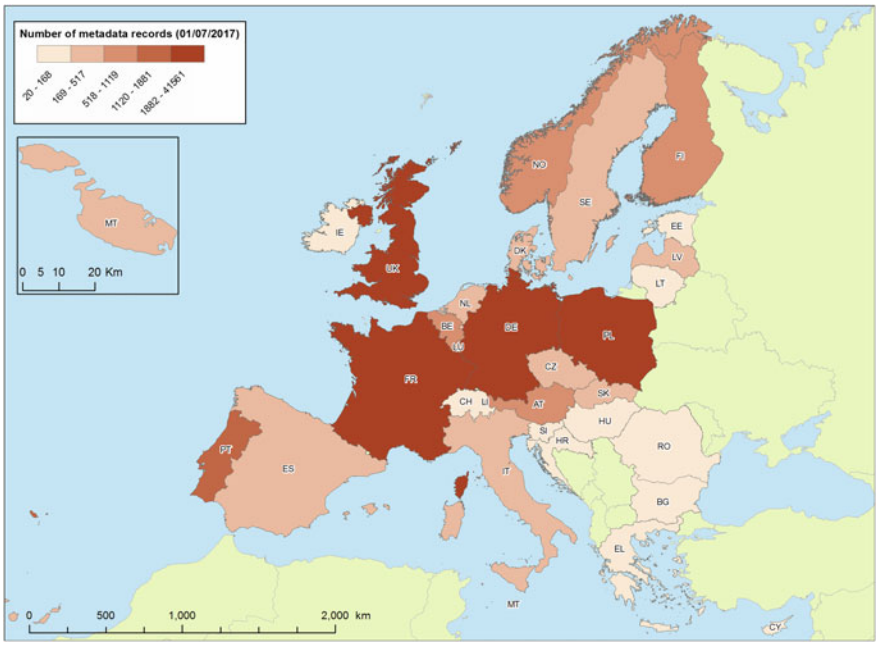

Fig. 3.8 Number of metadata records discoverable through the INSPIRE Geoportal (as of 01 July 2017). *Source* EC, Joint Research Centre

through network services. Consequently, by December 2017, datasets that fall under the scope of Annex I are expected to be in place and interoperable. Similarly, by the end of 2020, data for Annex II and III should also be conform to the Directive's requirements.

The mid-term evaluation of the status of the Directive's implementation was carried out in 2014. The results showed that a satisfactory evolution of the issues addressed by INSPIRE has been taken place. Increasing volumes of geospatial data are becoming available through the infrastructure. Figure 3.8 gives an overview of the metadata that is currently made available within the infrastructure by using discovery (CSW) services. The evaluation highlighted some ongoing challenges that include the need for coordination on multiple levels, as well as a more profound role of the private sector (European Environment Agency 2014).

Beyond this formal monitoring, collaboration can also be seen through many occasions where public authorities share their experiences, lessons learned[7] and work together to make the most out of the infrastructure.

[7]https://inspire.ec.europa.eu/document-tags/inspire-your-country.

3.3 SDI as a Catalyst to Change

There are multiple benefits associated, directly or indirectly, with the implementation of the Directive. We present our perspective on the important technical aspects that have been emerged in recent years, but an exhaustive list extends the scope of this chapter.

3.3.1 Data Interoperability

By far the largest effort in implementing data-related projects is data collection and processing because of its time consuming, tedious and expensive character (Longley 2005). Within this context, data interoperability streamlines the use of geospatial information. As already outlined in Sect. 3.2, the INSPIRE data specifications were elaborated through more than 10 years of engagement of hundreds of experts, representing all thematic areas covered by the Directive. Several cross-theme activities took place to keep coherence and consistency across domains, eliminate overlaps and guarantee high quality as well as relevance in each theme.

Interoperability of spatial data allows cross border and -thematic usage. As such INSPIRE could be seen as the "lingua franca" for geospatial data in Europe. The core data models as contained in the legal framework can be extended, following the rules defined by the generic conceptual model (European Commission 2013) and the documented semantics. This is one aspect of flexibility that preserves interoperability when applying a data model for a specific use case. It is also worth noting that on a technical level, many of the data and feature types are reused in different data models. This helps to ensure consistency across the infrastructure. Furthermore, adopting INSPIRE facilitates cross-domain interoperability, i.e. data from multiple domains are easily combined and used together. Examples include analyses in a cross-cutting setting, such as environmental impact assessments (Vanderhaegen and Muro 2005), natural hazards and disaster reduction (Tomas et al. 2015) or exposure science and spatial epidemiology (Elliott and Wartenberg 2004).

3.3.2 Streamlined Data Governance

INSPIRE is conceptualised in a way that it does not hamper processes internal to individual organisations. Instead, it helps to break silos of existing information within the public administration and streamlines data related processes on several levels. Besides the obvious gains from the improved interoperability with others, implementing the Directive offers additional benefits. They are associated with an

optimised internal data management in public administration, such as (i) operating an inventory of available resources through metadata, (ii) avoiding duplication of data-gathering between organisations (once-only principle), (iii) using services for internal purposes, (iv) establishing rigid identification patterns for spatial objects based on Uniform Resource Identifiers (URI), (v) making data and information available for the private sector and citizens, including reinforcing e-Government initiatives and (vi) supporting open data developments that can help to release more data beyond the scope of the Directive.

When extended to the national level, the streamlined data governance approach leads to the establishment of an efficient governance structure. In some cases, such as the Dutch "public geo datasets at your service—PDOK" (Kruse 2016), the obligation to transpose and implement INSPIRE on a national level started a process through which heterogeneous actors were assigned clear roles according to their own data responsibility. This helped to avoid duplications in data storage and created a collaborative environment with different parties. From a governance perspective, the implementation effort has also aided coordination between public sector actors which includes different (sub-national) levels of government. Many issues are addressed in such contexts: (i) joint decision-making on specific data sets within the infrastructure, (ii) how to make data available in a most efficient manner, (iii) under which conditions data will be shared, (iv) how to maintain the infrastructure and its data, and (v) how to reach the users inside and outside public administrations.

INSPIRE is likely to be the most complex and geographically extensive SDI initiative in the world nowadays. The lessons learned from its data harmonisation activities in Europe are highly relevant to the global agenda. They have been recognised, for example, by the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM CoE 2014) and the Global Earth Observation System of Systems (GEOSS, Butterfield et al. 2008) as notable European contributions to efforts on this topic.

3.3.3 Service-Oriented Architecture (SOA)

As outlined above in Sect. 3.2.2.3 INSPIRE utilises the SOA approach, where data are exposed in a distributed manner through web (network) services. These services allow to process existing geospatial data and are based on well-established standards. There is a growing number of readily available client applications (web, mobile, desktop) that can be used in order to consume the available data. Furthermore, services are reusable by definition. Geospatial data and metadata are independent from a particular use case and can be easily accessed.

Considering the diversity of different organisational settings and types of data within the infrastructure, a high-level objective is defined: data should be kept and exposed where it can be managed most efficiently. The implementation of services also facilitates the distribution of the most up-to-date information. Through the

establishment of network services, INSPIRE is already triggering a paradigm shift that implies the establishment of architectures for 'pulling' geospatial data in contrast with the traditional approach for 'pushing' data to a centralised repository (see e.g. Kotsev et al. 2015).

There is no universal solution to fit all possible use cases regarding the establishment of services. In most cases, data are served close to the data provider, i.e. on a national or sub-national level. At the same time there is an increasing number of cases where the national coordination body is supporting data providers through a common technical infrastructure (e.g. Malta, Finland, and Czech Republic).[8] Similarly, this 'aggregation' approach is followed on a European level by thematic umbrella organisations, such as EuroGeoSurveys.[9] In some cases the distributed SOA is supplemented by a central infrastructure component, which has been put in place for performant access to pan-European data. Examples of this approach include monitoring invasive alien species through the European Alien Species Information Network—EASIN (Katsanevakis et al. 2015), industrial emissions (EEA 2017), air quality (Schleidt 2013 and Kotsev et al. 2015), and geology.[10]

From our perspective, the benefits from the exposure of data on multiple levels are manifold. Data models offer inspiration and a starting point for data users to create their own outputs. Apart from the value added, due to the implementation of network services, there are several challenges to be addressed. They are mentioned in Sect. 3.4.

3.3.4 Flexible Technical Development

The Directive and implementing rules are neutral from a technological and application point of view. They do not require a particular technology to be adopted. Existing technical documents only provide guidance on how particular requirements may be approached by using selected technological solutions. There are many options for data providers to choose from, depending on their particular needs. The described technological flexibility allows the uptake of emerging trends from relevant domains such as linked and open data, Internet of Things and cloud computing. This adaptability for future requirements can be seen as characteristic to make the infrastructure future-proof. At the same time, considering how fast the technological scenery is changing, the question on which technology should be adopted, remains open. There is clearly a trade-off between restricting the technological choices in order to ensure stability and interoperability (i), and adapting the infrastructure to new trends (ii). From our perspective, preference should be

[8] https://inspire.ec.europa.eu/Monitoring-and-Reporting/Monitoring-and-Reporting/.

[9] http://www.europe-geology.eu/—EGDI—European Geological Data Infrastructure.

[10] http://minerals4eu.brgm-rec.fr/—EU-MKDP—European Union Minerals Knowledge Data Platform.

given to emerging technologies that not only satisfies the requirements of the Directive, but also provides additional value to providers and users of geospatial content.

3.3.5 Community of Practice

Over the years, it has become clear that stakeholders, who participated in the development and implementation process, have a sense of stewardship of the results (Dawes 2010; NRC 1994). They ensure that the data specifications are aligned to particular needs, reused and semantics preserved. Furthermore, these processes have led to the establishment of a European SDI community of practice. The European Commission is supporting this community by coordinating the INSPIRE Thematic Clusters Platform.[11] It provides an online collaborative space that (i) facilitates the sharing of implementation experience, (ii) optimises the infrastructure, (iii) supports the policy objectives and (iv) increases INSPIRE's usability across thematic domains.

As practical implementers of INSPIRE, the community of practice not only maintains the infrastructure but also caters for its evolution, reflecting emerging technological trends and societal requirements.

3.3.6 Innovative Apps and Value-Added Services

A key aspect of INSPIRE, as other SDIs, is that it is not an end in itself. The data infrastructure is a means to mobilise efforts and resources around guaranteed, consistent, high quality and trustworthy data-sharing across Europe. Third party solution providers that have not necessarily participated in the establishment of INSPIRE are provided with a unique opportunity to build value-added applications and services. They no longer need to invest in costly data discovery and processing. Instead, developers can concentrate on innovation and improving their products. At the same time, some of the software developed to support the implementation and use on national and European level (e.g. the INSPIRE Registry[12] and Find Your Scope tool[13]) are released as reusable free and open source software tools. Such an approach can be seen as example of reuse of public goods.

In addition, public authorities in their attempts to improve and optimise the services which they provide to citizens are increasingly involved in the development of new online services. Many of them have been built on top of geospatial

[11] https://themes.jrc.ec.europa.eu.

[12] https://inspire.ec.europa.eu/registry/.

[13] http://inspire.ec.europa.eu/portfolio/find-your-scope.

data provided through the infrastructure, while (appropriately) not necessarily recognising the efforts to get such content to them. That is how INSPIRE is reinforcing the agenda related to e-government (recently referred to as digital government).

The following example highlights value added modifications in the Austrian geoinformation management. Austria defines a digital agenda for its e-government (eGFS 2017) and therefore authorities are motivated to go beyond an infrastructure on the basis of minimum consensus. The first step, but not the easiest one, is collaboration in data collection e.g. production of orthoimageries (OI) or Airborne Laser Scanning (ALS). At least each partner should make use of products under their own license model. Even the distribution in Open Government Data[14] should be enabled for all partners. Nevertheless, the main important aspects of infrastructural maintenance activities within authorities are transparency to all users, using responsible competences and enhancing quality in order to broaden the field of application. The technological framework of Service-Oriented Mapping supports these aforementioned aspects and results in economic, organisational and technological benefits.

This approach could be demonstrated trough federal maintenance of the data theme addresses. Addresses are core data because of their extensive use and key-role for the integration of geoinformation (geocoding). In Austria about 2100 municipalities collect the federal addresses. The central register of addresses instantly adds the geocoding on the basis of the Austrian cadastre and it includes several plausibility checks for quality control. In 2016 the quality of addresses has been enormously enhanced (Eurogeographics 2017) by using cross-linked geo-web services to the Austrian routes network.[15] A new workflow establishes a link from addresses to the nationwide transportation graph (GIP) which now enables the ability to route with these data. The address point is moved towards the route graph, but still stays within the parcel. The main aim for all stakeholders is to describe the access to the parcel. All involved geo-web services are autonomous, which means that the collection and initial quality control is not influenced by requesting "external" geo-web services at the GIP infrastructure. Asynchronous and periodical service mechanisms are installed to ensure a consistent dataset. Once more this example shows that collaboration leads to a win-to-win situation for all producing stakeholders: an enormous quality enhancement for addresses on one hand and precise routing functionality for the transportation graph on the other. The implementation as service-oriented architecture allows for flexible and productive linkage, which is almost independent from organisational structures. For the security of the system several specific mechanisms had to be enabled.

[14] https://www.data.gv.at/.

[15] http://www.gip.gv.at/gipat-en.html.

3.4 Discussion and Conclusions

Precisely 10 years after the adoption of the INSPIRE Directive, in this chapter we summarise some of the lessons learned, and discuss selected emerging trends that benefit the evolution of this pan-European SDI.

- INSPIRE, although not yet fully implemented, is effectively contributing to a European political priority of creating a Digital Single Market, by boosting the economy through the 'unlocking' public sector data.
- The Open Data movement and INSPIRE are mutually beneficial both in terms of development and outlook.
- INSPIRE represents a paradigm shift from 'data push' to 'data pull' that enables the reuse of data. These data are being made available from where it is best managed. This not only helps to build innovative apps, but also facilitates an evidence-based policy-making process.

At the same time, technological developments and societal challenges associated to digital transformation are quickly evolving. From our perspective, the inclusive and flexible approach used for the development of INSPIRE should continue to be applied in addressing them, in collaboration with other actors beyond the initial scope of the Directive. Sharing such experience across sectoral domains and disciplines is fundamental to reap from the investments done. Several technological challenges are addressed to ensure the sustainability and evolution of the spatial data infrastructure.

The full potential for production of innovative applications and services based on the content of the INSPIRE Geoportal[16]—a single point of access to all MS data and services—is yet to be reached. The recent JRC activity of developing "thematic views" on the Geoportal content (e.g. priority datasets for eReporting) follows the simplification of use direction defined by the Better Regulation principles.

In general the discoverability of geospatial data on the web remains a challenge. Being based on OGC standards, data in INSPIRE is accessed through the interaction with different services (CSW, WFS, WMS, etc.). Their use requires specific knowledge and often at least some understanding of the underlying infrastructure. This may be relatively clear to GIS users but limits the use of the data and services by others—non-expert users that prefer e.g. common search engines to discover content. This issue is addressed by a recent study (Geonovum 2016) and is being explored further at the JRC.

The infrastructure should adapt to changing technological trends. In that respect, new guidance may be produced that add value to the infrastructure while ensuring compliance with the legislation. Some of the questions to be addressed include e.g. the establishment of RESTful web services, use of asynchronous event-based architectures for data retrieval, encoding of data through GeoJSON, or JSON-LD (JavaScript Object Notation for Linked Data, JSON 2017).

[16] http://inspire-geoportal.ec.europa.eu.

Common semantics for spatial objects across Europe, documented in the central INSPIRE Registers, has been one of the most important interoperability achievements of INSPIRE that must be preserved and updated as requirements may evolve in the future. Common semantics achieved in INSPIRE also facilitate integration of data from different communities as well as sources (e.g. use the INSPIRE objects for eReporting (Schleidt 2013).

Emerging trends related to the use of cloud computing would optimise the performance and scalability of the service-oriented architecture and underlying data. Furthermore, they provide an opportunity for data analytics to become an inseparable part of the data infrastructure that INSPIRE does not directly address yet.

A great deal of experience has been gained by public administrations through INSPIRE's implementation, bringing innovation at all levels of public administration. Consequently, more official data is available online across Europe. It is also in line with other legislation such as the Aarhus Convention (UNECE 2017) giving the public better access to information about the conditions of their environment.

As outlined, the implementation, due to its ambition and wide scope, follows a progressive approach, according to different National and European levels of priority. It involves transversally public administration at all levels. Therefore it requires efficient and effective national coordination and monitoring. This is done by the coordination body set-up in each country. Similarly at European level, coordination is guaranteed across related policies, using the Commission instruments, following the Better Regulation's principles (European Commission 2015).

The collaboration between experts in Member States' public and private sectors, software solution providers, open source communities, international standardisation organisations, professional umbrella organisations and European institutions, has proven to be achieving wide benefits that are holding up INSPIRE as an example to follow. Similarly, INSPIRE goals, achievements as well as difficulties represent unique knowledge to be considered in recent ICT policy developments in Europe, in line with the ambitions of the Digital Single Market.

Unlocking' geospatial data remains challenging, being the technological aspects the easiest to solve. Continued interaction between all parties will ensure that investments and ongoing implementation will create a sustainable and extensible infrastructure for European and global gains.

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