



## **Future research topics on Spatial Data Infrastructures**

In the first half of 2018, it was decided to end the Global Spatial Data Infrastructure (GSDI) Association. This association was dissolved as a legal entity in October 2018. Since its inception over 20 years ago, GSDI has delivered 15 World Conferences, provided funding for Small Projects developing Spatial Data Infrastructures in nations around the globe, facilitated extensive knowledge-sharing across an international network of geospatial professionals, and published SDI news appreciated by many thousands of readers globally.

In this context, Open Geospatial Consortium and EuroSDR are exploring if there is a specific need for a follow-up initiative focusing on the knowledge sharing aspect concerning the developments of spatial data infrastructures.

A first start of this exploration was the development of a survey consisting of four questions. This short questionnaire was sent to the delegates of EuroSDR and was briefly introduced during the Commission 5 reporting at the 133rd Board of Delegates meeting in Berlin (15 November 2018). The delegates had the time to respond until 10 December 2018.

The four questions were the following:

- 1) What are the current key research topics in the context of Spatial Data Infrastructures?
- 2) What are the expected future key research topics in the context of Spatial Data Infrastructures?
- 3) Is there a need for an independent network organization focusing on SDI knowledge transfer?
- 4) What follow-up actions do you recommend?

The first answers results were briefly presented at the OGC University Domain Working Group (UDWG) meeting (Charlotte (USA), 12 December 2018). They partly formed the basis for discussion. The main outcome of that meeting was to continue the discussion with a more formal discussion during the next UDWG meeting in Leuven (Belgium) being part of OGC TC/PC meetings (24-28 June 2019) regarding how to formalize OGC/EuroSDR initiatives to sustain the academic focus on SDI research. This will allow to consider where EuroSDR and OGC activities might align to advance common objectives – given the many topics in the survey that currently overlap OGC areas of emphasis.

This is a summary report of the questionnaire results compiling all the answers received from the delegates. The report presents all the answers for each question as well as a short associated summary of the key findings. The presented answers are direct answers given by the delegates, and so no modifications to the answers have been taken place. Some delegates requested that the answers should be 'anonymized'. Therefore, it is not clear who of the delegates gave which answer. It is tried to categorise the given answers by topic and/or similarity in response.

In the next section, an overview of delegates from the different organizations who responded to the questionnaire is presented. In the follow-up sections, the answers to each question are presented in a separate section.

## **Response**

Seventeen responses were received from the following organisations:

- Federal Office of Metrology and Surveying (Austria)
- National Geographic Institute – Belgium (Belgium)
- University of Zagreb (Croatia)
- Department of Lands and Surveys, Ministry of Interior (Cyprus)
- Estonian Land Board (Estonia)
- National Land Survey (Finland)
- IGN France (France)
- Ordnance Survey Ireland (Ireland)
- Delft University of Technology (Netherlands)
- Kadaster (Netherlands)
- Statens Kartverket (Norway)
- Surveying and mapping authority of the Republic of Slovenia (Slovenia)
- National Geographic Institute Spain (Spain)
- Lund University (Sweden)
- Swisstopo (Switzerland)
- Ordnance Survey Great-Britain (United Kingdom)
- University College London (United Kingdom)

Being aware that EuroSDR consists of 18 member countries, the response from 15 countries can be considered high. The only countries that did not respond were Denmark, Germany and Poland. The responses came from 13 national mapping and cadastral agencies and 4 universities.

## Question 1: What are the current key research topics in the context of Spatial Data Infrastructures?

The following answers were received:

- New Open and agile formats for transfer data. Until now the most used formats for geographic data (shapefile, ECW...) are not completely open and it is necessary to research on some aspects of the new candidates, for instance GeoJSON and Geopackage: best way of coding vector and raster data in new formats, how merging two or more files, optimizing new codifications
- A new web services architecture is needed, as far as the most used OGC standard (WMS) is almost 20 years old. OGC is now working in this direction in order to use OpenAPI as a basis.
- API strategies
- Harmonising and agreeing standards - still relevant but needs to move on
- Standards
- Developing lighter versions of standards developed for traditional SDI (like GML).
- Content versioning
- Providing standards for (web)developers
- Data exchange (formats, data harmonization)
- Data exchange standards are well covered by OGC and ISO TC211
- OGC WFS 3.0 – a good example of how an SDI standard is moving forward
- Standardization of datasets and e-services
- W3C/OGC spatial data on the web interest group – considering how to use contemporary web tech for spatial data – best practice publications
- Geodata on the web
- Metadata quality, applying ISO 19157 to describe the quality of the metadata catalogue contents
- Displaying quality metadata
- How to make links between SDI, data quality and metadata, in particular for online data sources – working towards data repositories that can automatically update information, data services and so forth using standards-based protocols
- SDI Quality. There are some studies evaluating the global quality of an SDI, but any of them is definitive and we think more research is needed on this topic
- Evaluating and documenting quality: either intrinsic quality (wrt specifications) or with respect to a usage
- Linked Data and Ontologies applied to SDIs. There are several interesting aspects: publishing and managing feature and full datasets by means of linked data and ontologies, and also managing metadata and SDI resources in a smart way applying LD &O
- Connecting national SDI and metadata system with open linked data approach
- Linked data
- Linked data
- Service / application interfaces on Linked SDI data - merging spatial data and mainstream - incl. methods to search and link (RDF) spatial data, web based spatial generalization and coordinate transformations
- Simplification of the distribution workflows
- Spatial data generalization issues
- What is the best way to present (visualize) results and quality of data processing either through an SDI or another online service. What are appropriate visualization techniques, would alternatives such as traffic lights work?
- Specifically for INSPIRE how European countries can communicate data better via an SDI. Some case studies exist, more are needed

- Period which lasted now for 10 years and will last for next 2 can be defined as INSPIRE-period in which most research has been focused on establishment of INSPIRE defined structures and instruments. Today we are aware that SDI is much more than INSPIRE defined frame for SDI on public data produce by (mainly) governmental bodies
- Consider the developments of INSPIRE
- Knowledge extraction – add processing capability to SDI to enable use of Big Data; use of semantic web techniques and linked data
- OpenSDI – Focuses on “producers”: Linking authority SDI to VGI and private data, openness in all aspects including open governance is the idea, Questions about liability of these joint SDI
- Open and easy access to available datasets
- Open data
- Security, Access control
- HUB technology providing a two-way engagement platform to connect government and citizens and to engage with the wider customer base outside the traditional industry
- VGI and SDI. There are some very interesting studies in this area, but any definitive way of taking advantage of VGI for underpinning SDIs
- 3D-data. See e.g. the ongoing EuroSDR GeoBIM-project which has implications on future SDI
- Interoperability between GIS and BIM (EuroSDR’s GeoBIM, ISO/TC 211 and ISO/TC 59 SC 13 cooperation on GIS (Geospatial) / BIM interoperability)
- 3D data including GML encoding
- User requirements and methods for complimentary integration of satellite data (Sentinel) and SDI dataset entities
- How to increase the usage of National Spatial Data Infrastructure
- SDI Cost/benefits and impact analysis. There is a lack of this kind of studies and it would be great to have a general methodology to be applied
- Safety and privacy
- Spatial data integration and GDPR (at large)
- License of use
- Interconnection with thematic data, statistical data
- Digital heritage SDI
- Use of SDI in emergency response
- Another development influencing research in the context of SDI’s are various other infrastructures which have evolved in past years which are supporting “applicative” concepts like Smart cities, Intelligent transportation systems, precise farming, climate change, etc. (on one side) and commercial infrastructures which underpin services like Google and others
- Managing several perspectives in terms of geographic data models (semantics and geometrics): depending on the place (in particular country) and on time, relevant concepts to describe space may vary as well as choices made by societies. SDI should support decisions based on multi-sources
- PPP initiatives. There are a big duplication of efforts in the field of GI looking at the private and public sectors. Innovative approaches are needed to allow governments to play their role (to produce quality reference data and services) and support private sector activity (develop applications and exploit public resources)
- Political/strategic questions
- Multilingualism
- Education and dissemination

- We are currently working on a new solution for SDIs. So far we have been outsourcing both the development and maintenance of important spatial data services to private companies. After the IT field consolidation process, there is a new policy according to which the necessary infrastructure for SDI will be provided by the IT Centre of the Ministry of the Environment and our task will be the development of services. Therefore, the amount of work in the form of support contracts outsourced to outside partners will decrease. In cooperation with the IT Centre of we are testing the compliance of cloud solutions with spatial data services. In addition, we are also in the process of using the data exchange layer X-road more as an important component of SDI

#### *Summary of the answers*

A long list of current key research topics in the context of Spatial Data Infrastructures have been provided with a very wide range of topics including issues related to technology, standards, legislation, quality, management, finances, and usages. The most outstanding topics specifically refer to research issues related to Standardisation and Linked Data. Other research topics frequently mentioned are: Process Management, INSPIRE implementation, Metadata, Volunteered Geographic Information/Crowdsourcing, Geodata on the Web, APIs, 3D data, GeoBIM interoperability, Open Data, Privacy, Security, Smart Cities, SDI-use and visualisation.

## Question 2: What are the expected future key research topics in the context of Spatial Data Infrastructures?

The following answers were received:

- Linked data
- Linked data publishing
- Linking data (in UK there is a project on this sponsored by Geospatial Commission)
- Ability to put linked data
- Knowledge extraction – add processing capability to SDI to enable use of Big Data; use of semantic web techniques and linked data
- Use of the semantic web to manage spatial data quality
- Maintaining links between interconnected contents
- Cross border content homogeneity among European countries
- Large and small scale environment monitoring as a SDI service using e.g. sensor data and analytics; algorithms and deep learning - to enable wide variety of possible ecosystems and applications with added value services (although Google is probably on the way already)
- INSPIRE accessibility of data. Spain offers most of national and regional data throughout INSPIRE services, but at European context there still lack of data
- Main services (WMS and WFS) + other possible service types
- Analysing user queries on geoportals to adapt the user interface and displayed features
- Central access point with authentication
- Access control to commercially sensitive data
- Despite GML was defined as format candidate for INSPIRE datasets, it is still not broad used  
There are more preferred formats among users such as GeoJSON or private standards
- Automated or semi-automated edge matching, taking advantage of machine learning
- New formats and data integration in SDIs: 3D, panoramas, video, LiDAR data
- 3D-data. See e.g. the ongoing EuroSDR GeoBIM-project which has implications on future SDI
- Switching from 2D to 3D geodata will raise all basic research topics, we have solved in 2D again: data format, standards, data management, data query, data dissemination, data visualization, versioning, etc.
- Technologies for a wide range of data applications (analysing, visualisation)
- Datacubes as means for harmonization and efficient access technology for SDIs
- How to extend SDIs to indoor environments, taking into account BIM and Internet of Things
- Connection between SDI technology and Smart Cities. Until now there are to some extent separated arenas
- Use of an SDI to support a smart/sustainable city
- Integration of GIS with other sectors, like ITS (Intelligent Transport Systems) and Smart Cities
- How to move from existing SDI ways of working to utilize latest technologies including cloud, APIs/service infrastructure. Systematic ways of sharing spatial data
- Process automation
- Metadata generation simplification by means of machine learning, automated generation and so on
- What are the links between metadata and provenance
- Change detection using digital aerial photos and imagery
- New data capture technology (UAVs, LiDAR)
- Implementation of dynamic datums

- Real time SDI is a major research gap - how to manage real time data in the SDI and in particular how to combine the static and real time data to solve problems. For example, the Icelandic volcano needed to combine real time flight information and ash cloud information and more static background data, a river pollution case needs to combine real time pollution data with background population data, an earthquake needs to combine real time data about damage and population movement, with underlying based data about the population. Should the SDI provide both the real time and the base data or just the base data? How to make people aware of the sources of data?
- Including time series adds research questions on top of 3D
- Automatic update techniques
- A whole Preservation methodology applied to SDIs, especially to INSPIRE SDIs is needed
- Archiving : cold and warm archives, how to decide so as to improve SDI footprints
- How to promote Open Data and Services. Unfortunately less than the 11 % of GI is published as Open Data (Global Open Data Index) and this is one of the biggest barriers to the development and spread of SDIs
- Specifying what shall be core data, considering also for instance stable landmarks that can be used across time
- OpenSDI – Focuses on “producers”: Linking authority SDI to VGI and private data, openness in all aspects including open governance is the idea, Questions about liability of these joint SDI
- Crowdsourcing
- Literacy, fact checking application: have citizens learn to use data and to adopt a critical perspective wrt information derived from data. Also to ensure that we can trust knowledge grounded on data
- How to be sure that data is shared should in fact be shared (e.g. licensing), are reliable, trustworthy, and don't violate GDPR
- SDI is broader than technology and standards. The areas of governance would benefit from further research (data sharing agreements, privacy, cost and licencing)
- Different governance models for different situations. How much governance do you actually need?
- Development of principles to develop a national digital twin, and governance around them
- SDI needs to look much more at the end users and to specific case studies from the end user perspective
- Data and dissemination of the data should become more accessible and usable, also for people outside the traditional geo domain
- Use and user driven
- I would say that future of SDI's depends on research topics which will make them efficient for users. This covers conceptual, organizational and technical issues in general. Kind of sub research topic remains to find proper form, volume and methodology for transfer of knowledge to new and existing professionals. This issue seems still not be solved in satisfactory way, where at the same time new related issues are appearing (and complicating picture) like EO based geoinformatics in general
- Evaluating a community or an individual capacities wrt contributing to geographical data
- The owners/experts currently control the location products and information in the actual Spatial Data Infrastructures (SDI). This concept is out-of-date and must be replaced in a short time by Spatial Knowledge Infrastructure (SKI), which is open-sourced and interactive
- Designing new SDIs from scratch, such as the INSPIRE 'what if' sessions
- Going from the point that we need structured spatial data organized in infrastructures on various levels, question open for future: what is and how should look like (in Europe) future (E)SDI concept and what are the steps which have to be undertaken to achieve next level
- Integration with mainstream eGovernment solutions (reuse existing vocabularies in the geospatial domain, IoT, ++)

- Having reusable SDI components –transversal to technologies (i.e. sentinel data, in situ data, structured data) that can be easily discovered and reused from users, i.e. from a perspective of an application, from a developer who maybe does not need to know all the complexity of geodetic coordinate systems or of geometry modelling
- (Administrative) multi-level integration - national, regional, local – hub of hub, community
- A transformation from static Spatial Data Infrastructures (SDI) to dynamic SDI demands new techniques and further research
- Effective data management
- SDI usability, which is in fact a partial aspect of SDI Quality
- Propagation of uncertainties between observations and simulated models (simulation can concern the completion of representations when observations are lacking, or the representation of possible scenarios (flood, regulations, climate change)
- Research is needed to demonstrate the advantages of the standard services on new areas of activity, especially in private sector
- Research and orientation onto new markets for Geodata/Location Technologies -> Mobility, finance business, asset management, insurance, smart city and the role of the administration bodies within those sections
- Follow the activities of ISO and OGC

#### *Summary of the answers*

A very long list of expected future key research topics in the context of Spatial Data Infrastructures have been provided with even a wider range of topics than presented under Question 1. The future research topics that stand out refer to Linked Data, Open Data, 3D data (modelling), Time management (including time series, real time), Smart Cities and User-centricity. It is remarkable that most given topics are only mentioned once. In comparison with the answers of Question 1, standardisation as a research topic is not mentioned frequently.

### Question 3: Is there a need for an independent network organization focusing on SDI knowledge transfer?

The following answers were received:

- Yes, of course
- Yes, absolutely there is a momentum as national SDIs are currently maturing
- Yes. The network should include academia, NMA, crowd source groups and private companies
- Yes, there is a need, but we do not reclaim a network organisation with a strategic focus. We postulate a rather praxis oriented network organisation, which aligns its focus with explicit uses cases and real current demands
- Yes, it would be very helpful
- Yes, but a “small one” to coordinate
- We believe that a lot of worldwide countries already has developed the National Spatial Data Infrastructure, so maybe the organization focus could be on the less developed countries
- Not so sure. It is important is to have more dialogue between the end users of SDI, like DG Env wrt INSPIRE, and the SDI components providers (content, software) and to involve industry who can process metadata in a smart way. We think the sequential view : “producer publish data, these are discovered and reused, sometimes a feedback somehow gets to the producer” is not very efficient nor pragmatic and that we need solutions where the content provider and content consumer dialogue –like in an AGILE development process. We also think it is important between users and content providers to agree on SDI scopes –is there one big infrastructure where all data is registered somehow or do we need rather, as was proposed in the literature, several interconnected SDIs that address specific scopes
- Perhaps not an organization but there is a need for a mechanism to do it through an existing organization. Such at OGC, UN-GGIM or ICA
- We believe that it is not necessary. SDI topics can be covered under other working groups’ activities. However, if there were a working group we would definitely consider participating
- Geonovum fulfils this role in the Netherlands with close collaboration with research institutes and universities
- I would say in general there are so to many organizations. If question is focusing on global organization I would say no. There is UN-GGIM, and many other organizations. On the European level we have EuroSDR which is covering related topics and we don’t need another organization
- There are several existing network organizations within SDI (OGC, ISO, EuroGeographics). We do not see the need for a new independent network organization focusing on SDI knowledge transfer
- No, but this subject must clearly be identified and coordinated in the different existing entities (EuroSDR, EuroGeographics, UN-GGIM, OGC, ...)
- No, these issues can be handled through OGC and INSPIRE and ISO through specialist working groups

#### *Summary of the answers*

The answers are very mixed. Six answers explicitly express a need for an independent network organization focusing on SDI knowledge transfer, meanwhile six answers explicitly express that there is no need. The remaining three answers are not explicit if there is a need for such organization or not. In the scope of the development of spatial data infrastructures, Europe benefited a lot by the adoption of the INSPIRE EU Directive. As such Europe stands out in comparison with other regions worldwide. It is very likely that other regions are more in favour of such an independent network organisation for SDI knowledge transfer.

#### Question 4: What follow-up actions do you recommend?

The following answers were received:

- More focus on user groups. More focus on creating operational web services. Less focus on collecting small-scale global data
- Next actions should start with some workshops and webinars focussing on:
  - o What is the next stage for SDI to discuss whether SDI should exist at all, and if so in their current format, as well as to cover the topics above and come up with a research agenda
  - o Followed by more specialist workshops such as Provenance and SDI, Trust and SDI, Real time data, static data and SDI
- A good way of exchanging knowledge and experience would be a workshop for covering SDI topics. Newer OGC and INSPIRE topics would also be suitable to be included in the agenda
- An initiative (working group) to collect, evaluate and tackle concrete, common use cases of the NMCAs'. Giving best practise solutions and answers to some specific use cases
- Consider the proposed future key research topics, revitalise the work on linked data . There were several activities on LoD but few mature and sustainable implementations
- Examples of good practices. How different datasets can be used for applications, analysis, cross-border actions,...
- To explore the topics above to make data easily accessible and usable for the wider community and users outside the traditional geo-domain
- In case that actions carried out during years by GSDI Association would be continued by other initiative, it should be broadly promoted among national and regional SDI coordination bodies because they would become in the first receptor of knowledge or directly participation in the network
- Clarify what is open data licences and promote a consistent policy in this domain, especially wrt ODBL licence and data production funded by EC
- Mitigating between core data (stable landmarks) and models mediation to achieve user-oriented products
- All researches, advances and knowledge should be shared in an open way to facilitate the interoperability and awareness transfer. Remained that all possible actions in this field always need to be connected with standardization bodies to ensure continuation of current developments, such as INSPIRE, OGC, ISO and national standardization bodies
- Probably, it would be wise to support complementary activities in several organizations: research projects can be carried out in EuroSDR and other actions of sharing knowledge (good practices and experiences) inside the International Cartographic Association (WG on standards and SDI)
- I feel a discussion on the definition on the concept of "SDI" is needed. The definition of what an SDI is has changed so fundamentally in the last 2-3 years it has become unclear in the wider community as to what it is and the role it plays
- There are 2 years till final INSPIRE conference in Dubrovnik (2020.) I could imagine that EuroSDR could consider task to analyse situation and figure (E)SDI2030 goals
- Examine closely the implementation of INSPIRE Directive, identify deficiencies, and recommend ways for improvement
- Have a look to the "Springer"-book „Service-Oriented Mapping“

#### *Summary of the answers*

The recommendations for follow-up actions are very diverse ranging from the organisation of workshops, focus on specific user groups/topics, collection of good practices, discussion on a redefinition of the SDI-concept, setting up relevant governance structures to monitoring the INSPIRE implementation. It is remarkable that half of the recommendations refer to be more user-centric or to widen the scope of user community.