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Adaptive Development of a Regional Spatial Data Infrastructure Facing Local Prospects and Socio-Technological Trends

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Abstract. The regional Lounaispaikka-SDI (Spatial Data Infrastructure) in southwest Finland is being developed by a dynamic assembly of the region's geospatial expertise and its networking, spatial data and geoportal services. Emerging as a data-centric constellation that supported the region's geographical information professionals, this assembly has developed into a geospatial service with more broadly-focused public information on the region. This development has had five adaptive phases, each as a response to changing local needs and fast-evolving trends in information and communication technologies. Alongside these processes, the Lounaispaikka-SDI has also reinforced the region's geospatial competencies with benefits offered to academia, public sector institutions, and companies.

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1. Introduction

Spatial Data Infrastructures (SDIs) combine cooperation networks and user-centred solutions with technical architectures for seamless data access and related applications (Rajabifard *et al.*, 2006). In spatially enabled societies, SDIs foster efficient, flexible and shared use of Geospatial Information (GI) and thereby assist community development. SDIs can be found in multiple domains, ranging from the global to the national and regional. There are also thematic SDI initiatives, such as those concerned with marine and coastal environments (e.g., Strain *et al.*, 2006; Tolvanen and Kalliola, 2008), or those meeting specific academic needs (Coetzee *et al.,* 2017; Da Dilva and Camboim, 2018).

The first generation of SDIs in the 1970s were institutional or sectorial databanks, but with limited user focus. After the US National Spatial Data Infrastructure (NSDI) was established in the mid-1990s, SDIs started to support broader groups of users as well (Masser 1999). In the early 2000s, this development initiated the second generation of SDIs, which aimed at more functional geoportal solutions (Masó *et al.*, 2012). An important milestone was the INSPIRE directive of the European Union (EU) launched in 2007 (INSPIRE 2007). The third generation of SDIs (from the 2010s forward) shifted toward interactive user-oriented solutions with volunteer GIS and crowdsourcing opportunities (Budhatoki *et al.*, 2008). For example, since 2004 the OpenStreetMap consortium has enabled enthusiastic amateur mappers to produce local knowledge for new geospatial information (Sadeghi-Niaraki *et al.*, 2010). In the late 2010s, increasing the links of GI with a variety of other open information sources and a semantic web may lead to the fourth generation of SDIs. For example, Iwaniak *et al.* (2017) have examined how GIS data can be converted into user demanded knowledge, thereby supporting new kinds of purposes.

In many countries, SDI development has primarily focussed on national-level needs with close ties to governmental data policies and practices. In some places, the top-down approach is complemented by regional (sub-national) schemes that may have evolved more freely in direct response to the specific conditions of their operative regions. For this reason they help to study how demand-based, cooperative SDIs, with their unique societal impacts, can actually evolve. In this paper we report the case of the regional "Lounaispaikka-SDI" in SW Finland. This infrastructure was initially set up as a collaboration network between regional public geospatial data actors; however, it has grown into one of the strongest regional SDI frameworks in that country. Being locally inspired and having persisted for a considerable time, Lounaispaikka-SDI may reveal mechanisms that can help other SDI compositions, too, to appraise their changing role amidst the dynamic advancements in information and communication technologies (ICT), spatial data and social habits.

2. Materials and methods

The focus area of the Lounaispaikka-SDI covers an area of about 20 000 km^2 and a population of *circa* 500 000 inhabitants – almost 200 000 of them in the city of Turku. The infrastructure is provided by seven public organisations, all of which benefit from positive visibility due to their engagement. The strongest impetus for the public authorities (two Regional Councils, the Regional Environmental Center, and the city of Turku) comes from the synergy benefits that they get for their GI operations – especially for data sharing, networking, and augmented professional competence. The two participating universities, in turn, are motivated by their interest in SDI-related research and education as well as the internship and job possibilities available to their graduates.

Our analysis first offers a retrospective narrative of the overall development of the Lounaispaikka-SDI from its initiation to the present form. As source materials, we used unpublished Annual Reports from 2000–2016, notes from development group meetings, and a variety of related internal documents. All these materials were examined against the rapidly developing fields of ICT and international-to-national SDI developments. For reference materials, we used literature sources (e.g., Crompvoets *et al.*, 2004; Vandenbroucke *et al.*, 2009; Grus *et al.*, 2010) and policy documentation available on the Internet. Finally, we address the ma-

turity of the Lounaispaikka-SDI as an established data infrastructure (cf. De Man, 2006; Craglia and Campagna, 2010). We used an ordinal classification scheme with four levels (none, low, intermediate, high) to analyse the following characteristics:

- Trust and partnership (between the actors and institutions involved),
- Prospect of endurance (anticipated from the referred development phase onward),
- Spatial data resources (amount, quality and uniqueness of data resources),
- Variety of services (number and quality of the functional GI-based services),
- Significance to NSDI development (professional collaboration and contributions),
- Regional significance (complementing other regional activities and region-building processes), and
- Reception by users (levels of use and acceptance by the targeted audience).

3. Results

The development of the Lounaispaikka-SDI into its present form has had five consecutive phases, each with its own set of new ideas and perspectives (see Table 1). Simultaneously, the SDI geoportal has undergone fundamental changes in used Internet technologies, service design and outreach (see Fig. 1).

Table 1. Major functional characteristics of Lounaispaikka-SDI's services during its five developmental phases

Functional characteristics	Data-centric (1999–2001)	Networking (2002–2008)	Geoportal (2009–2011)	GI Service (2012–2014)	Information (2015–present)
Efforts to support the region's GI community	Institutional co-operation to promote regional GI synergies	Institutional and professional interaction	Network expansion with new partners	Long-term funding for the secretariat	Collaboration with other regional information producers
	Promotion through regional GI days for a broader audience	Competence sharing with NSDI	Participation in the national INSPIRE working groups	Increasing use of social media	Integration within the regional open data community
		Own stand at the National GI Expo		Support for PGIS and VGIS	
Efforts for concurrent geospatial data and technologies	Gathering of all kinds of available GI from the region	New thematic data gained through projects	Shift from commercial to open-source software	Oskari.org platform taken into use (as in the NSDI)	Links to textual and statistical data resources
	Use of commercial software for web-map service	Improved map service	Inclusion of INSPIRE data in a regional context	Shift toward increasingly open data and software	Enabling of map embedding in other websites
		Pioneering WMS in Finland			Development of WFS services
Efforts to establish user needed services	Early versions of GI metadata with simple tool for search	More advanced metadata catalogue to help in finding relevant data	Tailored in-house programmed geoportal with regional scope	Living links to external geoservers to enhance data access	User-centred design for a regional information portal with GI
	Ordinary Internet page configuration for users	Piloting spatial data lending	Design of the "Paikkaoppi" GI learning environment	Programming of events to develop novel GI services	Events for brainstorming, crowdsourcing, programming

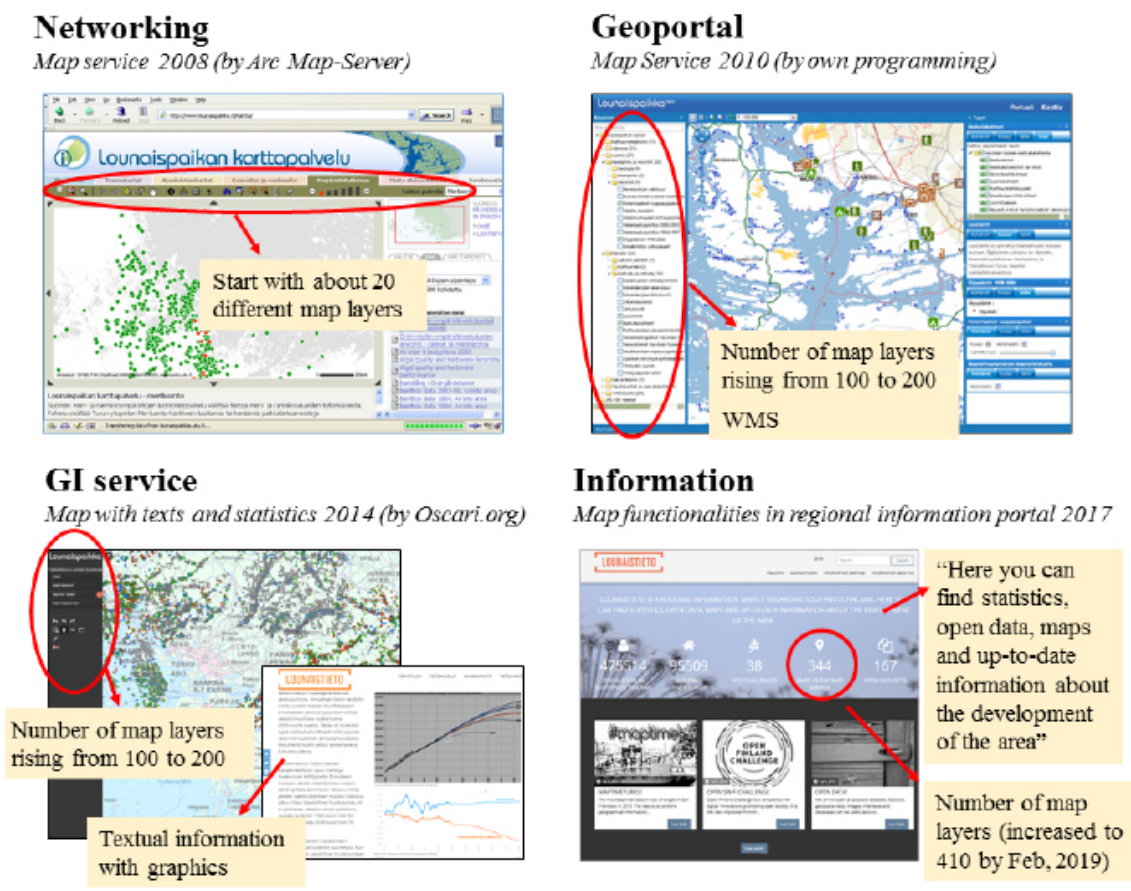

Fig. 1. Snapshots of different Internet service generations from the four different phases of Lounaispaikka-SDI development

The Data-centric phase (1999–2001) sought to improve overall regional geospatial data identification and access, all of which were at that time restricted by such hindrances as absence of geospatial data policies, poor metadata and weak institutional confidence in digital data sharing. The Networking phase (2002–2008) emphasised thematically designed GI services, such as map viewing and data lending (Toivonen and Kalliola, 2007). WMS (Web Map Service) was implemented during this phase as one of the earliest Internet platforms with this technology in Finland. The Geoportal phase (2009–2011) introduced a new-generation web service based on open source in-house programming. The goal was to gain flexibility and freedom from commercial software. Also, lots of locally available geospatial datasets were collected from data providers in the region. Lounaispaikka-SDI competences were also contributing to national-level GI training through the "PaikkaOppi" digital learning environment (Riihelä and Mäki, 2015). The GI Service phase (2012–2014) was begun after the realisation that much of what had been new and innovative earlier at the regional level, now needed to be renewed due to the rapid advancements in overall SDI technology. The open source map server technology "Oskari.org" (Oskari, 2017) was adopted because it was also used in building the NSDI geoportal. This decision liberated regional human resources to address increasingly local information needs. Special programming events called "mapathons" were arranged to develop new types of GI services. The Information phase (from 2015) advanced from this stage as a response to the ever-increasing demand for a broader array of public information through the web. The data and services of the Lounaispaikka-SDI were consequently integrated into the more widely-scoped regional information portal "Lounaistieto", which provides access to plentiful open public information as texts, pictures and statistical data. Brainstorming and crowdsourcing events were frequently held with university students from differ-

ent scientific disciplines to boost new uses and service concepts for open GI.

The above-described phases of the infrastructure's development coincided and interacted with the overall progress and advancements of the developing ICT and SDI fronts (see Fig. 2). For example, the Finnish NSDI building, which is steered by the National Advisory Board for Spatial Data (acronym PATINE), has formulated four consecutive National Spatial Data Strategies, each reflecting the changing roles and expectations of SDIs in society (PATINE 2004; PATINE 2010; PATINE 2014; PATINE 2017). In conjunction, the Lounaispaikka-SDI has operated as a proactive, flexible and adaptive actor with close linkages to the development of the NSDI. Lounaispaikka-SDI's early focus on data discovery and access was reduced after the Finnish public data policies were liberalised in 2012. Instead, the regional SDI started to emphasise the piloting of new kinds of GI services, some of which later contributed to the national spatial data strategies and geoportal construction. Although some service types of the Lounaispaikka-SDI were temporarily among the forerunners in Finland, new versions of the NSDI geoportal and some awesomely powerful map viewers produced by international companies became superior in many fields. Still, many locally produced GI types are exclusively available through Lounaispaikka-SDI.

The maturity assessment of the Lounaispaikka-SDI shows a steady increase with time (see Table 2). Since its start as an informal initiative by GI professionals with no clear perspective on its continuation, overall confidence and trust have steadily increased. The information phase already enjoys a good level of commitment, and the SDI is also reinforced by its integration within the broader context of public information delivery. Through this merger, locally powered GI services are increasingly used in education and everyday life. Lounaispaikka-SDI also has a special mention in the regional development strategy of south-west Finland. Further, the community behind Lounaispaikka-SDI is increasingly involved in cooperating with companies. Despite all these advancements, however, Lounaispaikka-SDI has not yet reached full maturity. For example, the unpublished Annual Report from 2018 distinguishes many further development needs in the user interface and user interaction, the available GI resources, and institutional engagement. Functionalities such as Web Feature Service (WFS) are currently being developed.

4. Discussion

Mapping systems have evolved as a co-evolutionary narrative between map producers and users as part of the overall techno-social advancement of cartography (Burnett and Kalliola 2000). Spatial data infrastructures continue this development by linking the innovations in information, surveys, and communication technologies together in the context of geospatial information. They are established through a consistent development agenda – as the implementation of the INSPIRE directive is – or as dynamically changing constellations with many distinct development paths over time (Crompvoets *et al.*, 2004; Hendriks *et al.*, 2012). A degree of spontaneity is thus inevitable because SDI construction is inherently multi-dimensional, and many of its building blocks, such as technical standards and their possibilities or actor cooperation and partnership relations, can be hard both to predict and then to control (Vanderbroucke *et al.*, 2009; Grus *et al.*, 2010).

Lounaispaikka-SDI has been successful in resisting the pressures posed by changing local needs, NSDI development and the disruptions of the evolving ICT. Over time, the key strategy has been ongoing agility through adaptive development. This trait has involved frequent rethinking of both the operational environment and the interim objectives. Ultimately, these changes have required substantial flexibility at both the personal and institutional levels. The evolution has thereby been organic, such that preceding developmental phases have formed the basis for subsequent ones. Although much of what was at one time considered current may have shifted from the primary focus, the legacies of the past – and the traces they have left – have constituted a valuable resource. In this sense, the studied case exemplifies the process-oriented SDI development track wherein the basic condition from acquisition of information to its delivery has given way to an increasingly complex array of users that inter-

Table 2. Ordinal grading of the attributes describing Lounaispaikka-SDI's maturity through its five developmental phases

Maturity characteristics	Data-centric (1999–2001)	Networking (2002–2008)	Geoportal (2009–2011)	GI Service (2012–2014)	Information (2015–present)
Trust and partnership	low	low	intermediate	high	high
Prospect of endurance	none	low	intermediate	intermediate	high
Spatial data resources	low	intermediate	intermediate	intermediate	high
Variety of services	low	low	intermediate	intermediate	intermediate to high
Significance to NSDI development	none	low	intermediate	intermediate	low
Regional significance	none	none	low	low	intermediate to high
Reception by users	none	low	low	intermediate	intermediate

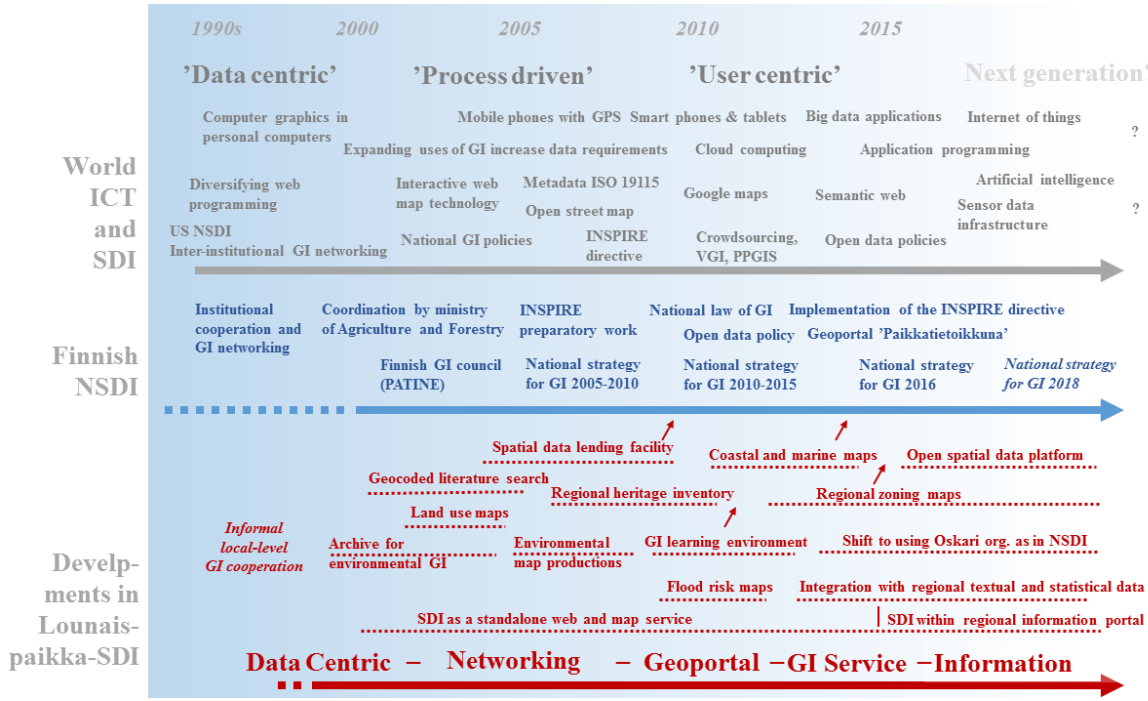

Fig. 2. Sequence of events during the Lounaispaikka-SDI development and their relationship to the parallel evolutions in ICT, SDI, and NSDI. Small arrows denote the concrete contributions of the Lounaispaikka-SDI on the national level

act with GI producers (Elwood, 2008; Budhathoki *et al.*, 2008; Vandenbroucke *et al.*, 2009).

Our analysis also reveals how changes in the universal ICT and geospatial developments continually challenge the plans and schedules of arduous geoportal building. Officially-steered SDI development may look to some actors to be too slow, technical or bureaucratic, while the overall trend emphasises open standardised interfaces, increasing user involvement, operational flexibility and crowdsourcing. Also, new technologies, such as data being linked to expert systems and artificial intelligence, now provide unprecedented possibilities for future SDIs (Iwaniak *et al.*, 2017). Public processes are also challenged by private firms, as they are increasingly eager to take part in open-data initiatives, yet some may have reservations due to the risks of leaking valuable product information (Perkman and Shildt, 2015).

Under these circumstances, regional SDIs can offer substantial benefits for their spirit and closeness with the user community in their area of operation. The lightness and agility of a small SDI provide the flexibility to tailor locally acknowledged solutions that can encourage even small actors to take part, and indigenous data is often appreciated alongside the big data from national or global sources (Kitchin and Lauriault, 2015). A well-functioning regional SDI also manifests the competences of the professionals working in the region and thereby supports provincial self-esteem. It remains to be seen, however, how regional SDIs will find their best place under the pressure of future NSDI geoportals and competent international companies that do hold vast amounts of all kinds of data and can provide powerful services with the help of crowdsourcing and artificial intelligence. Therefore, a clear but adaptable vision is indeed needed to keep the regional SDI construction manageable and avoid undesired drift (de Man, 2006).

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