Sharing and Coordinating SDIs in the Age of Crowdsourcing and Mobile Technologies

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Abstract. Every spatial data infrastructure (SDI) reflects an evolving concept related to the facilitation and coordination of the exchange and sharing of spatial data and services. Today, SDIs are evolving in response to the mushrooming of cloud-based and location-based services, neogeography, crowdsourcing and volunteered geographic information (VGI). In this paper we consider the underlying and fundamental changes for SDIs arising from crowdsourcing and mobile technologies. We take SDI development in support of common needs in government and society as reference frame for the discussion on SDI evolution. We also provide evidence that SDIs will continue to play significant roles as sources of authoritative data for web-based services. The development of facilitation and coordination capacities can come at different phases of development. In fact, SDIs less encumbered by complex institutional arrangements may be able to leverage crowdsourcing and mobile technologies more readily and support cartographic activities.

Keywords: spatial data infrastructure, crowdsourcing, mobile technologies, volunteered geographic information, SDI development, SDI evolution

1. Introduction

Spatial data infrastructures (SDI) developed to support government activities when paper maps and corresponding cartographic production arrangements were being replaced by digital geographic information.

Although geographic information can be used, and is certainly used, in the production of maps, the replacement of maps with digital data and networked availability of this information opened up new possibilities (Masser and Campbell 1991). Indeed, the first concepts for national SDIs focused on institutional arrangements to support these possibilities. SDIs have evolved to become keystones of large information management activities in smaller governments, private industries, and non-profit organizations. Instead of single, centralized SDIs, an archipelago of SDIs characterizes the current status.

The move to more devolved approaches has allowed SDIs to rapidly become central to many administrative activities while retaining agency level flexibility. The push/pull of centralization and decentralization characterizes many SDI initiatives. The dynamic balance found in the development of any SDI seems largely to reflect institutional and other factors. It of course changes as technologies change: standards, ontologies, integration issues continue to lie at the forefront of research and practical challenges.

Currently, the rapid growth of mobile technologies and the related improvement in possibilities of crowdsourcing geographic information holds profound challenges for SDI initiatives that have, in many cases, only recently found acceptable arrangements to address service-orientated architectures and related cloud-based data storage and computing possibilities. Evidence suggests that new phenomena are already impacting data collection and sharing in SDIs (C0leman et al. 2009, Genovese & Roche 2010, Al Bakri & Fairbairn 2011, Sui et al. 2013), but the past will continue to affect the development of SDIs in future (Harvey et al. 2012).

As SDIs develop in response to new technologies, how are they evolving? Do they come together as more centralized repositories for authoritative data? Do they fragment into more mission-focused SDIs with smaller scopes and reach? Are they becoming hybrids that institutionally keep centralizing and decentralizing tendencies at bay? Will SDIs develop in a much more dynamic and even at times capricious ecology of interactions involving data?

In this paper, we consider these changes starting from considerations of the different ways that SDIs have developed to support a broad range of diverse, yet fundamentally common needs of government and society. We focus then on newer technologies and approaches we see can augment and strengthen existing strengths of SDI initiatives. Also, our considerations take into account that the SDI concepts are themselves changing.

2. SDI developments in response to common needs

SDIs at the national level have evolved in response to common needs related to the sharing and coordination of geographic data (see Figure 1). These needs existed before computerization was widespread, but only the wide-scale use of information technology makes it possible to fulfill these needs in such systematic and fundamental ways (Harvey et al. 2012).

A key common need behind the development of SDI is *decision support*. It has long been recognized by policy makers that high-quality information and analyses are prerequisites for good policy-making (Densham 1991). If most government activities and decisions are spatial in nature, then the ability to locate activities and develop models of spatial consequences is key to reliable governance.

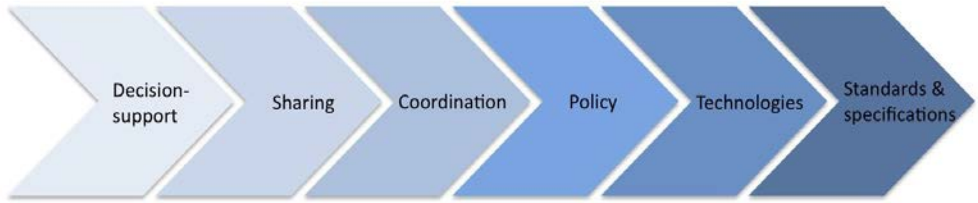

Figure 1. Common needs related to sharing and coordination of geographic data

The proliferation of GIS along with the ability to infinitely reproduce copies of data opened possibilities for sharing geographic information. With the possibility of sharing arises a need to *share*. While information technology facilitates sharing, it is generally tempered by a desire to cover costs, create revenue, or grow programs. Geographic data re-use is a central incentive for public administration SDI investments.

While sharing is possible, for sustained sharing to become more meaningful, the need for *coordination* becomes apparent. Fundamentally, coordination can also improve the effectiveness of SDIs by improving the cost-effectiveness of data collection, maintenance, and updating by taking multiple needs and uses into account.

Of course, the facilitation of geographic information collection, maintenance, and updating soon requires a framework beyond informal *coordination*. The need for policy arises with the intent to assure that benefits are not outweighed by costs to keep sharing and coordination going.

With increased capacities, new potentials follow, and improvements, successes, and failures lead to a need to *keep up with new technologies* and maintain existing technologies. The increased use of remotely sensed land cover data is an excellent case in point. The rapid growth in LiDAR applications offers yet another example of how technological developments rapidly alter the potential of governments to improve services and improve the efficacy of their SDIs.

Moving away from centralized and unique organizational approaches, the need for *standards and specifications* to facilitate data sharing arises from the needs to coordinate multiple agencies arrayed in evolving fashions and to improve the uptake of new technologies into functional information infrastructures. The primary sources for standards for geographic data and services are ISO/TC 211, *Geographic information/Geomatics*, and the Open Geospatial Consortium (OGC).

3. SDI evolution in response to crowdsourcing and mobile technologies

SDIs originated in an era when national mapping agencies, such as the Head Office of Geodesy and Cartography (GUGiK) in Poland, were the sole source of geographic information in a country. Technologies and circumstances have evolved drastically since then. While the need for a nationwide SDI focus at the national political level remains, SDIs of today have moved away from national small-scale data to more people-relevant large-scale information (Rajabifard et al 2006). Here we describe the impact of VGI, crowdsourcing and mobile technologies on SDIs.

3.1. The need for decision support

Crowdsourcing and mobile technologies are changing the perception that authoritative data is a prerequisite for good decision support. Citizens can now provide information for decision support. For example, in South Africa, Mobilitate[1] allows citizens to log and prioritize service delivery complaints via mobile phone or the web. The exact location of the complaint is pinpointed via Google Maps. Mobilitate forwards complaints to the relevant municipality and notifies the ward councilor. Citizens and government officials can follow all communication and updates online, helping to keep government accountable. Since September 2010, more than 8,600 complaints have been reported countrywide, with 58% already fixed.

For all institutions, the ease with which individuals can collect information and associate it with location has opened vast possibilities, as the example from South Africa above shows. Different organizational and political

[1] www.mobilitate.co.za

cultures in the US have approached the potential in a variety of ways. Drawing on the many years of experience with citizen-based watershed watches, some agencies develop training programs and regular meetings to help interested citizens learn how to use the technologies and follow data collection protocols. In other cases, non-profit groups of volunteers organize the training and conduct focused data collection campaigns. OpenStreetMap mapping parties are an example of this approach known around the world.

The recent conviction for manslaughter of six scientists and an official in Italy for not predicting the 2009 L'Aquila earthquake (Nature 2012) shows that the consequences of providing poor data can be serious. While staff of official mapping agencies should be aware of the liabilities, this is unlikely to be the case with the public at large. However, volunteers contributing data for humanitarian reasons under severe time constraints could face tort liability (Robson 2012).

3.2. The need to share

Despite investments in metadata repositories and spatial data discovery services, according to an unpublished study by one of the authors only a small percentage of users in Poland use the official catalog services to search for geographic information. Most of the time general-purpose web search engines, such as Google or Bing, are used to look for geographic information, even though their metadata is not as descriptive as that in a catalog service. Such users are also more likely to look for geographic information in openly available data repositories than official SDI geoportals.

New approaches, such as cloud platforms, VGI and crowdsourcing make it easier to address the need to share. In addition, open source software for geospatial is increasingly available for sharing geographic data over the Internet. For example, the Open Source Geospatial Foundation[2] (OSGeo) lists at least nine different web-mapping products on its home page. A variety of location-based social networking sites, such as foursquare[3], allow the sharing of location information with so-called friends, which raises location privacy issues. When is it safe to share one's location? May the shared location information be archived for later analysis?

The viability of crowdsourcing approaches has fundamentally altered approaches to SDIs by opening up new potentials for data collection with

[2] www.osgeo.org

[3] www.foursquare.com

inherent changes for sharing. In the United States, the recently published National Academy of Science report, *Advancing Strategic Science: A Spatial Data Infrastructure Roadmap for the U.S. Geological Survey* (NAS 2012) lays out policy guidelines with relevance for discussions in other large data producing organizations in the USA and elsewhere. Fundamentally, the report points to the importance of maintaining data standards, data management, and application services to fulfill organizational requirements. The implementation depends on strategies and leadership, organizational culture, standardization, technical competence, funding, cooperation and partnerships. Similar emphasis is evident in the *Business Plan for the Geospatial Platform published by the Federal Geographic Data Committee* (FGDC 2012). Organizational and political challenges lie in desires to reduce expenses by streamlining operations and consolidating infrastructure. Centralized enterprise approaches aim to concentrate infrastructures physically and organizationally. The technology remains the same, but institutions are consolidated.

3.3. The need to coordinate

Originally, SDIs provided access to data produced by government entities with a formal mandate to provide, update and maintain geographic data (i.e. data custodians) and that are required to adhere to government policies and legislation, but that are also funded to fulfill these roles. However, such funding is becoming constrained in many countries, so as well as the ‘push’ of VGI becoming available, there is also the ‘pull’ of mandated agencies needing to source data more widely and more cheaply. VGI contributed through a single platform, simplifies coordination, while crowdsourcing already implies that some form of coordination exists.

The frequent ad hoc fashion of VGI contributions brings new coordination challenges. Siebritz et al. (2012) studied changes in OpenStreetMap data of South Africa for the period 2006 to 2011. The results generally show that the rate at which data is generated varies in space and time and that social events, such as the 2010 World Cup, resulted in a surge in VGI. The quality of VGI also varies among different communities. The implication for SDIs and national mapping agencies is that the integration of VGI cannot be coordinated in a uniform way across the country. Siebritz et al. (2012) concluded that presently VGI is unlikely to be of a quality as good as the authoritative data from a national mapping agency, but that it could be useful in other ways, for example, to identify gaps or inaccuracies in authoritative data. Using such sources coordinated through the SDI is much more cost effective than having to do field work.

In Poland, examples of VGI abound, mainly for roads and tourist destinations. Allowing the general public to edit and update authoritative SDI data, such as the cadastre, is of course not possible due to the legal implications of changes to such data. However, citizens can assist to verify data and improve its quality. Ten years ago, the *Poviat* of Wroclaw was one of the first public bodies in Poland *adminstracji* to publish orthophotos, topographic, cadastral and planning data online. At that time, the rules for data publication were not yet conclusive. There was an initial reluctance to share cadastral data, due to the fear that inaccuracies in the data would result in claims and grievances from citizens. Some of the authors of this article were involved in a project in which simple portal functionality for electronically submitting comments on the boundaries of land parcels was introduced. Many comments were received and analyzed. As a result, the quality of cadastral data in Wroclaw improved significantly but at a relatively low cost.

3.4. The need for policy

The technology for aggregating data is readily available and the benefits are at hand. The aggregation can be accomplished by transforming data formats and assuring that the attributes are properly documented. As Craglia, Ostermann, and Spinsanti discuss in a recent paper (2012), with such ease, the benefits can be significant for institutional missions. Even from unstructured data in multiple languages, crowdsourced information can be used to verify official information and used to identify further cases.

However, the sharing of crowdsourced data is a challenging policy issue when new datasets are created from the integration of multiple source data sets. If the license agreements of source data sets differ, it becomes a challenge to negotiate a license agreement for the integrated dataset. There are calls for the standardization of license agreements (Welle Donker et al. 2010), which will simplify the integration of data from a variety of sources. Standardized license agreements will also simplify the flow of data among SDI stakeholders and between different SDIs.

A survey among Polish students shows that there is still a strong perception in Poland that administrations are the sole owners of geographic data. Most students consider it acceptable practice that administrations acquire geographic data free of charge from surveying companies and then provide commercial services that compete with those provided by other businesses. Such a mindset is a barrier to a market-driven approach to applications and services.

3.5. The need to keep up with technological developments

Smart phones and their capabilities are changing SDI user expectations. Instead of a web interface, users want to view and interact with geographic information on their mobile phones. GPS technology, embedded in mobile phones, has further changed user expectations: instead of users identifying their location on a map, the phone (GPS) does it for them. This creates the expectation that one should be able to access and interact with SDI data in similar ways.

There are distinct differences in how different cultures, nations or regions approach implementing applications. Dominant in the US, and larger parts of the world to differing degrees, are approaches based on opening up the SDI data and letting developers try their acumen to develop consumer-grade and professional applications, i.e. a market-driven approach. In other countries where data access is more restrictive, there might be an attempt to create exclusive data contracts or build capacity in government agencies, i.e. a government-centric approach.

3.6. The need for standards and specifications

The widespread use of SMS (short message service) and RSS (rich site summary) feeds to publish and share information on a variety of mobile devices and applications has resulted in standards, such as Open GeoSMS and GeoRSS, which add geographic information to an SMS or RSS feed. Open GeoSMS is an extended SMS that facilitates mobile communication of location content between different location-based service devices or applications (OGC 2012). GeoRSS[4] extends RSS feeds and enables the sharing and mapping of geographically tagged feeds. Both standards can be integrated into platforms for VGI and crowdsourcing contributions. The amount of information shared in an SMS is small in comparison to, for example, the data downloaded from an online geoportal, yet, the exchange frequency is likely to be higher in mobile communication. Standards for SDIs already exist (e.g. ISO 19115:2003, *Geographic information – Metadata*), but new standards are needed to integrate new technologies into SDIs.

Integration and harmonization can take place either at the data level or at the application level. No one in the US will want the federal government to harmonize the application data, only the base data, and then because of devolution, state and local data will often be quite different. Is this bad? Yes, from a government-centric approach. From a market-driven approach,

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[4] www.georss.org

it is an opportunity to be taken up by savvy businesses. In South Africa, there is evidence of both a market-driven approach as well as a government-centric approach, even within single government departments.

4. Discussion

New technologies and approaches make it easier to fulfill the common data sharing and coordination needs in an improved fashion. Increased integration from multiple sources requires simplification of data licenses and rights management.

Citizen involvement in data collection is realized in an increasing variety of applications, ranging from watershed watches to bird counts and crime hotspot identification. Data and services from official SDIs are not necessarily used. For each application there could be a small SDI, addressing the sharing and coordination needs within its scope of application.

The integration of crowdsourcing and mobile technologies into SDIs results in increased traffic, albeit in smaller chunks, suggesting increased dynamicity within and among SDIs. Standards and specifications need to be revised and/or developed to accordingly.

SDIs will continue to play a significant role as sources of authoritative data, but new technologies and methods hold the potential to improve the data sharing and coordination at lower cost. Users expect SDI data to be available through new technologies. The onus is on SDI stakeholders to realize the benefits of these new technologies.

5. Conclusion

Crowdsourcing and mobile technologies are having an evolutionary impact on SDIs. From the examples we consider different strategies. Clearly, the need is evident for further consideration of the future roles of standards and ontologies in assuring the integration of data sources for cartographic analysis and presentation.

Underlying locally distinct changes we see a commonality in how crowdsourced data enables the realization of SDI initiatives. Crowdsourced data should not necessarily be seen as competition for authoritative data produced within an SDI initiative, but rather as an ally.

In order to better understand SDI developments, empirical studies and exemplary analysis of SDIs in the changing realm of cartography can assess the hybridizing developments of SDI faced with crowdsourced data and mobile technologies.

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