Demands for a Spatial Information Infrastructure Fit for Cadastre 2034

Jürg H. LÜTHY and Christian KAUL, Switzerland

Key words: Digital Cadastre, GSDI, Cadastre 2014/2034; Spatially Enabled Society; 3D; 4D; traceability; integrity; Web-services

SUMMARY

With the change from mono-thematic cadastre to more complex and comprehensive information systems like Cadastre 2014 / 2034 and with the growing use of cadastral and spatial data through web-services the requirements for cadastral applications are changing significantly. A new generation of spatial information infrastructure must be built. The paper describes the general demands for such a system.

The future infrastructure must reuse established concepts and core functionality: The system must be data centric and not product centric. A strict separation between data storage, application and presentation layer will, therefore, allow a broad usage of data in different applications and devices. The internet as communication infrastructure and web-standards build the foundation of the infrastructure.

One of the big challenges will be the provision and support of a holistic data quality: The barriers for data users have been massively minimized and a big variety of data sets can be consumed conveniently through web-services. This makes forgotten that the entire infrastructure may not be free of errors. To ensure correct data the entire infrastructure must support a service quality instead of data quality only. The service quality is subdivided in availability, traceability and integrity. On the functional level the system must be capable to handle 3D and 4D (temporal) data to support the challenges of a rapid urbanization and mega-cities cadastral system. The challenges herein are the correctness of topologies. Besides well-established visualisation applications the core requirement of cadastral systems like topological data quality, clearly defined data maintenance processes and data analysis are not yet standard. .

The divided responsibility over information from real world objects makes a coupling of cadastral with other information systems necessary. Such a coupling should not only allow data integration (SES) but also data synchronisation for ensuring the consistency between the different data sets.

Demands for a Spatial Information Infrastructure Fit for Cadastre 2034

Jürg H. LÜTHY and Christian KAUL, Switzerland

1. INTRODUCTION

After the initial work for designing and developing digital cadastral system and huge investments in the data collection a change of focus in spatial data handling can be observed over the last years. Many data sets have been built up and made available through spatial data infrastructures (SDI) to a wide community. Cadastral data are essential in (almost) every SDI since the property information is relevant for all land use planning activities but also for all kind of rights and restrictions. The range of users has been broadened from specialists to every citizen utilizing a variety of devices for spatial data presentation. Alongside with the intensified data use a transition from product centric thinking (plans) to data driven products can be observed.

The way of accessing spatial data reflects still today in many cases the silo thinking when building up data infrastructure. Information drawn on a map are stored in a spatial data base, files in a separate data set, even they both describe the same real world phenomena. For many task such separation is hindering an efficient use of already existing data sources. The integration of spatial and textual data is beneficial to overcoming the silo structure and providing holistic information (Phlipps et al. 1999, Kaufmann et. al. 2012)

On the data provider side two main observations can be made: Firstly, with the change from mono-thematic cadastre to more complex and comprehensive information systems like Cadastre 2014 the technical challenges for data providers will significantly increase. In order to provide integration capabilities the SDI must support various web-technologies and is faced with safety and security issues. Secondly, with (near-) ending of the initial data collecting data producer are faced with a switch from mass data acquisition to selective data maintenance the importance of data acquisition is lower than of data provisioning. While it is acceptable in large data acquisition project having a separation between field surveys (aerial photogrammetry, airborne laser scanning inter alia), data pre-processing and data extraction such cumbersome processes are not adequate for single feature updates. The entire data chain for maintenance and updates of real world phenomena must therefore become lighter, i.e. using apps on sensors for directly updating data in a central database. On the other side data sets covering restrictions and responsibilities which are usually defined in political processes must provide traceability from data request down to the consumer.

The aim of this paper is to foster the discussion about future demands for data provisioning and data infrastructures from the user side and elaborates on a conceptual level six thesis based on the experiences as data provider and SDI operator in the Cadastre 2014 era. The thesis can be regarded as enhancements of the FIG Report on Spatially Enabled Society (Steudler et. al. 2012). Because of the emphasis on integration of data from various sources it is suggested that the current SDI should be become a *Spatial Information Infrastructure* (SII). The herein listed demands are technology-oriented but it is evident that the challenges can only be achieved if the entire cadastral community supports also in their attitude the transformation processes.

2. DEMANDS FOR A SPATIAL INFRASTRUCTURE

2.1 Core Concepts

Thesis 1: Spatial data build the foundation of Spatial Information Infrastructure

2.1.1 Explanation

Maps have served traditionally as condensed storage for different kind of information (relief, transportation network, natural and man-made structures). With the market entry of Google, Bing and others the use of structured digital spatial data shifted from expert users to *consumers*. With the growing number of smart phone apps using mapping and localization services it is anticipated that the spatial information will follow the trend of "ubiquitous computing" and become permanently present. Therefore we expect a continuously growing penetration of spatial data in the society and need for effective and efficient geoinformation (Steudler et. al. 2012).

2.1.2 Rational

The significance of spatial data can be explained by three main assets:

- visualization of information;
- simplicity of combination of different data sets (mash-ups, overlays) and
- description of relationship between objects from different source using spatial analysis.

The complexity of large data sets can often be simplified by visualisations and the interdependencies between different kind of real world features, topologies and neighbourhood relations can be better understood when presented as map, especially in densely populated areas. Among the different Information Systems only the GIS provides as intrinsic capability the graphical presentation of its information (Goodchild 2007). Maps have always been of public interest and this is one reason, why multi-discipline collaborations should be strongly driven by SDI.

The benefit of developing common data model and exchange standard has been proofed in Swiss cadastral surveying. When starting the initiative for the reformation of cadastral surveying in the Mid-Eighties a standardised data model, a data model description and a data interchange format have been introduced. The Geo-language Interlis (cf. www.interlis.ch) provided the standard for describing and interchanging spatial data. With the formulated data model concept the thematic independent layers were also introduced. The early commencement of standardisation of spatial data in Switzerland was a pre-requisite for a straightforward setting-up of national and regional SDI following a new legislation on geospatial data (Kaufmann, 2010). Furthermore the initiation of the cadastre for public legal restrictions on landownership rights (PLR-cadastre) benefited from the investments in the data models since the technical fundaments of the cadastre architecture (organisation and structure of the SDI, common data models in a federal structure) facilitated the interoperability.

In the last decade a rapid change in the information infrastructure on the basis of internet technologies can be observed. One of the advantages of spatial data can be seen in the creation of mash-up, i.e. the combination of different information to create new knowledge. The implicit relationship between real-world features can be depicted by overlaying different data sources in a GIS. An explicit relationship (how many building will be inundated in a 100-year flood) can be derived using spatial analysis. The mash-up as a method to combine information from various sources and with different content is a traditional operation of GIS. Therefore, the spatial information will continue being a perfect base for future SII.

2.1.3 Consequences

The spatial information system fit for future demands can and must reuse established concepts and core functionalities. Many of them have been describe by Kaufmann (Kaufmann et al. 1998) when proposing Cadastre 2014: To allow maximum flexibility and to get an optimal return on investment in data capturing and maintenance, the system must be data centric and not product centric. A strict separation between data storage, business layer and presentation layer will allow moreover a broad usage of data in different applications and devices.
Many governmental and planning tasks do not stop at administrative borders; the importance of cross-border (semantic) interoperability is well known (Harvey et. al. 1999) and has been addressed by initiatives like Inspire. Yet, interoperability cannot be achieved using data models only but comprehensive feature capture rules and transformations (or mappings) will be needed in many cases too (Müller, 2014) . With the constantly growing number of web-services missing semantic interoperability may cause frustration at the user side and may lead to switching from governmental to privately or crowed-sourced data.
Besides the data organization a strong technical fundament for the provision of spatial data is indispensable. Compared to many other domains the OGC and ISO TC 211 standardisation committees paved the way for broader use of (spatial) data with the release of the various web service standards. Data providers have to build and maintain a strong technical fundament with high performance and availability in order to fulfil the increasing demand for spatial data. It must be expected that the variety of products derived from the different data sources will also increase because of the wider use of data. Hence an evolvement of data products is a continuing task.
Last but not least the legal base is in many countries not prepared for providing access to (digital) spatial data for everyone yet. Most of spatial data governing laws have been written in the analogue era and are not adequate to today's technical capabilities. A sound legal base is needed for setting up and governing SII with a clear positioning of SII as public infrastructures (see also Thesis 3). A legal base providing open access to spatial data is yet another important factor for a spatially enabled society (Rajabifard et.al. 2009).

2.2 Expand interoperability beyond spatial data infrastructure

Thesis 2: The benefit of spatial information can massively be increased by combining spatial and textual data

2.2.1 Explanation

The divided responsibility over information from real world or hypothetical objects makes a coupling of spatial information with other information systems necessary. Such a connection provides two benefits: the integration of fractured information over the same universe of discourse offers a holistic view. A real-time coupling of data sets through web services can further be used for the synchronisation of the data sets for ensuring consistency between them.

2.2.2 Rational

The modelling of real world phenomena is always coupled with a simplification and abstraction. Even though mapping allows dense information content it is in many cases not feasible to provide the universe of discourse in a map. Additional but separated data inventories likes registers and files for textual and drawings or pictures for visual information have often been established. Since different (technical) capabilities are required for each of the inventories the separation of data is often associated with a division of responsibilities: in many countries land owner register and cadastre are maintained by different organisations.

In the early era of digital information management attempts have been made for developing encompassing information systems but failed because of unmanageable complexity and because of diverging interest of the stakeholders. Systems designed for optimal support of individual business processes are common. When interdisciplinary or even multidisciplinary problems have to be addressed the separation of data turns into major barriers. Complex problems in densely populated areas with divergent interests of the shareholders can often be solved easier when a holistic view about real-world features can be provided.
Whilst basically each data set can be linked to any other, the spatial information is particularly suited as basis for mash-ups, data-linking and ad-hoc integration since many textual data sets describe localised objects (i.e. containing a spatial relation). As described in Thesis 1 maps are inherently suited for combining various kind of information by simple overlays hence the SII is predestined as linking platform. Additional information gathered trough mash-ups and integration are in contrast to "Big Data" analysis less comprehensively but the strict organisation of data maintenance and common keys as base for integration allow a high reliability of the analyses.
Cadastre 2014 implementation in the form of a PLR-cadastre in Switzerland showed already in the trial period the great advantage of providing holistic information to the end user (Lüthy, 2014).

2.2.3 Consequences

The way of accessing spatial data reflects still today in many cases the silo thinking when building up data infrastructure. FIG Report 58 (Steudler et. al. 2012) presented Spatially Enabled Society (SES) as an answer for the continuously growing demand for accessing spatial information. The report demands a sound data integration concept which offers the advantages of a holistic view where spatial and non-spatial data are integrated. The report request SDI to facilitate data sharing (open data), to reduce duplication and to link data producers, providers and value adders to data users based on the common goal of data sharing. Physical data exchange or even the building-up monolithic information systems is in the internet age unfavourable. Flexible data integration can be achieved through on-thy-fly data linking either through data-based web-services or through application-based communication (Hofer et. al. 2015). In the first case data sets are combined in the background and the integral view is provided through specialised web-applications to the user. The second method enhances existing (web-) applications by mutual interactions: actions in one application (like selections) may are propagated into other applications (like highlighting). Such a coupling is less tight but offers the advantage of re-using existing applications. The need for harmonising keys and object granularity across organisations for data integration poses an organisational challenge. The necessity of an agreement to cover the responsibility for inter-system communication is a second important task.
Fundamental requirement for service-based data-integrations is a stable, performant SDI as requested by Thesis 1 and stable "textual" data infrastructures. The outstanding starting position of spatial data providers for data linking shall be used to switch the focus from spatial data assembling, aggregation visualisation and provisioning to data integration. The technical capabilities must be supplemented with processing services. One of the common services is geo-coding which renders a textual data spatially. But because the relationship between textual data and space is often not explicitly defined further processing capabilities and spatial analysis must be built up. Such data integration services can also be used to improve the

referential integrity between different data sets: when the relation between two data sets is defined in integration rules amendments in one data set can be used for informing the other data owner about the update thus supporting the synchronisation between spatial and textual data sets.
The visualisation capabilities of today's WebGIS must be expanded from maps and simple tables to any kind of a data aggregation like pivot tables, diagrams and maps stories with maintained relationship between the different viewports (Lüthy 2014).
All technical capabilities are useless when data items are not identifiable over its entire live cycle. The importance of uniquely identifying (spatial) objects has been addressed by the EU directives on Inspire. Furthermore it must be understood that the life cycle of a real-world phenomenon may differ from the digital object. Instead of physically deleting objects in datasets as it is still common in spatial data the end of the lifespan should be captured as attribute.

2.3 Availability for users

Thesis 3: The demand for ubiquitous availability of spatial datasets will be increase: current data, real-time access, always, everywhere, fast and free of charge.

2.3.1 Explanation

With massive amount spatial data provided from internet companies at no charge, with the continuous expansion of usability methods (Apps with integrated maps and location based functions) and with the growing availability of high-speed internet the expectations on SII increase. Integration services require not only web-applications but standardized, service-based accesses to the public data. The open government initiatives will emphasize the expectation for free of charge access and use of spatial data.

2.3.2 Rational

The use of spatial data underlies a fast and significant change. Nowadays not the costly expert systems in which professional users analyze and combine spatial data are the main consumers but much more small and light applications , rapidly developed and thanks to the internet widely accessible for everyone ("apps"). With the popular use of smart phones everyone can localize its position almost always which fosters the demand for location-based applications. This completely reshaped approach of data utilization has a big impact on the requirements on data availability. As long as the data sets have been predominantly used within expert system the demand on availability has been restricted by the users work load for data access: few users had access to a several data sets. The service-based architecture allows a huge number of users accessing the same data source which demands much higher responsiveness and service performance.
The continuous growth of spatially enriched web apps is only possible thanks to faster and reliable internet-connections and a large repository of spatial data. User of the Web- and Social Media-generation share the expectation that data is up-to-date and free-of-charge. In parallel to the growing web-based data use the Open Knowledge Foundation has been initiated and established as a driving force for innovation (Jetzek 2013). Within the Open Government Data initiatives the free and open access to cadastral data is always at the top of the wish-list which again proves the relevance for spatial data in general and cadastral in particular as describe in Thesis 1 and 2. The pressure from the data integrators, apps developers and end users for cost-free dissemination of cadastral and spatial data should be

used for positioning SII as public infrastructure like roads, railways or schools.

2.3.3 Consequences

The shift from "heavy expert systems" to web-based access of spatial information must be taken for granted. Whilst the web-based use of spatial data (consuming) can be considered as state of the art the web-based data capturing and maintenance is – beside crowd sourcing initiatives – not common yet. Web-clients must be enhanced for data maintenance and standardized tasks (reports, analysis) and the SII must therefore consequently being designed as web-applications. With the opening of the SII for data updates the importance of safety and security will massively increase for ensuring data quality and service quality. When it comes to financial benefits people become very creative. If cadastral data like rights, restrictions and responsibility (RRR) can be updated via web-clients it must be assumed that some people may have the intention of hacking the system for personal advantages. In a mixed-use architecture a careful design is inevitable. A viable approach for cross-domain authentication is described in (Hofer et. al. 2015) but more work needs to be done to secure the entire SII. With the broaden use of spatial data and simple integration of mapping applets, open source libraries for data storage, rendering and processing, the development of spatial application will not be a specialized domain any longer. This easement may also be beneficial for countries with limited availability of cadastral data since it can be observed that internet and smart phones are penetrating also low-income countries (GSMA Intelligence 2015). The growing demand for free-of-charge spatial data should be used to position the SII as public infrastructure similar to roads and highways, paving the way for securing the funds for continuous enhancements of the SII. If successful the SII can benefit from political and financial support for the maintenance and continuous enhancements. The improved position of SII in the public perception will also increase surveillance and quality requirements.

2.4 Growing demand for reliable and trustable data

Thesis 4: A change from data quality to system quality is needed in the context of distributed data, shared responsibilities and decoupling data users from data owners

2.4.1 Explanation

Thanks to standardised web-services (WMS, WFS) the access to spatial data from remote system is nowadays trivial. In many cases a consumer of data in the internet is neither aware of the data source and its quality nor of the service provider and its service reliability. This tendency is amplified with growing data distribution through web- and integration services. On the other side, data providers becoming also more and more decoupled from the consumer side not knowing how their data is being used. This separation should be addressed by a shift from a data quality focus to a more comprehensive system quality focus.

2.4.2 Rational

The importance of spatial information is unquestioned. Spatial data infrastructures have become a central pillar for the development of modern societies. Whilst in early period cadastral data have been primarily used for securing the properties it is recognised that cadastral data are more comprehensive. Kaufmann (Kaufmann et. al. 1998) introduced the term legal land objects for the spatial representation of a law. In many cases the law if defining real world phenomena, rights or restrictions, is imprecise without associated spatial documentation. The concept of Cadastre 2014 proposed an inventory with legal land objects

(rights, rules, responsibilities). Today, many of such data sets like planning zones, natural protection areas are provided in combination with base maps and further data sets nowadays in publicly accessible SDI. The value of continuously available Cadastre 2014-like systems cannot be overestimated. Yet, in most examples which are known to the authors, the operators of the SDI are not fully aware of the significance and value of the data provided.
For most domain specialists the quality of the spatial data product should – if at all – be described by data quality characteristics according to ISO 19157:2013. With such a limited view on the data chain errors in the provision of data (defining data views, portrayal rules and transmission of data) cannot be detected.
On the data consumer side a huge number of data sets are used, combined and mashed-up without being aware of potential errors in the data. Free of charge, non-governmental maps services disclaim the responsibility for continuity of the data service and the correctness of the provided data in their service policies. Governmental, cadastral data must put highest priority for correct, reliable and trustable data and the contingency of data services also under adverse conditions.
At the start of the data chain (origination) it can be observed, that the importance for the correctness of legally defined land objects is not as good as possible. When building up the PLR-Cadastre in the Canton of Zurich it became obvious that the spatial representation was not always formally correct, because the amendment of the cadastre either did not undergo a public consultation or was not formally agreed by the superior authority. In other cases inconsistencies between data sets have been found. Because of the strict separation between law, cadastre and processes (or process documentation) the costs for searching the legally correct status or for formal putting into force ex post were huge. Whilst for *"right land objects"* (parcels) clear process definitions, qualification (chartered surveyor) and traceability requirements are in force since decades this must be introduced at least also for *restriction* and *responsibility* land objects.

2.4.3 Consequences

One of the big challenges for building SII will be the provision and support of a holistic data quality: To ensure correct data the entire infrastructure must assure a service quality instead of data quality only. The service quality comprehends in addition service availability, traceability and integrity. Service quality is a common characteristic in data infrastructures and inter alia also requested by Inspire.
For a data driven community the entire data chain, from origination to the end use must be better controlled. Traceability of information is in domains with high safety requirements like aviation an importance topic (Eurocontrol 2007, Reid 2008). Traceability must be achieved on a data level (i.e. supporting documentation for a feature) but also on a configuration level (i.e. documentation of data model, feature capture rules, presentation model).
Data originators must meet following requirements in future:

- Provide a data product specification including unambiguous description of the processes for data origination (cf. ISO 19131:2007).
- Defined appropriate data quality evaluation procedures including quality conformance levels (cf. ISO 19157:2013).
- Improved Metadata documentation by consequently using possibilities for traceability given by ISO 19115 (ISO 19115-1:2014),
- Providing tools and mechanism to support traceability from origination to withdrawal of

an object and integrate the traceability information,
– Periodic review and assessment of objects for ensuring integrity with associated laws (if no automated synchronization between spatial and textual data is feasible).
– Corrective action / feedback loop. With respect to error detection the wisdom of crowd should be considered.

To avoid decisions being taken with incorrect information because of errors in preparing or operating of services the entire process of data provisioning must be reconsidered. The integrity focuses on the process and service quality ensuring that data is not lost, uncontrolled altered or corrupted between origination and consumption.
The data and service provider have to establish a framework for a fully digital information data supply chain for enabling a modern and reliable cadastral information service. In a future SII an end user must have to possibility to verify the suitability of the data source for the given purpose and the correctness of data based on a comprehensive documentation of the data chain. Because the quality cannot directly be measured at the end users side, different approaches must be considered:
– Data Product Specification (DPS);
– Audits: the content of data service must be independently verified;
– Data protection (secured infrastructure);
– Service monitoring;
– Certificates for data, reports and services.

2.5 Encompass all dimension – from 2D to 3D and 4D

Thesis 5: The third and the fourth dimensions are inherent ingredient of the spatial infrastructure

2.5.1 Explanation

The core of most existing SDI is built up in 2D only: data base schema, business logic and presentation layer are all designed for 2-dimensional data sets. The continuous growth and densification of urban areas and hence increased complexity of land use activities must rely more and more on objects in 3D. In many land use planning processes a growing demand for historical data for visualizing and analysing the transformation processes can be observed. SDI must therefore include not only the current-state but span from past to present and future state (4D).

2.5.2 Rational

When the digitalization of the paper-based cadastral systems begun the focus lied in a one-to-one transformation of the existing information: 2D-maps were replaced by 2D data sets. Over the years selective objects have been enriched by height information, but most often not in the form of a true 3D object as additional but as separate information (spot elevation, building floor plan) to a 2D geometry. Many city models have been built up in the last decade underpinning the technical maturity of 3D applications but still today they are not integral part of the SDI. The barriers between current SDI and specialized 3D application hinder the broad use of 3D data sets. Although an intense research activity can be observed since several years the existing SDI must be regarded in general as 2D information system capable of handling limited information in the third dimension because several issues regarding legislation, data model and data handling are not yet resolved (Karki et al. 2013, Van Oosterom 2014).

The temporal aspects are also not yet incorporated in the application schema. The documentation of changes can usually be achieved only by a work-around. In the most trivial case a data set is extracted on a regular base from the database and copied as separate data set. In Switzerland small part of the cadastral data like parcels underlay a strict mutation process in which the history of the spatial object is recorded as metadata. The object itself usually does not contain its history and even worse related information like the building does not contain any historical information at all. A destroyed building is removed from the data set, leaving no traces. For a temporal analysis the different data sets (time stamped copies, metadata) may be aggregated and evaluated.
The drawback of such methods is the limited usability and the huge effort needed: for each temporal analysis a separate investigation must be performed. With the growing demand for trend and multi-dimensional analyses more scalable approaches are needed. Considerations on how effectively enhance a cadastre with the time dimension are made in several countries (Van Oosterom 2014, Vučić 2014). To better support the challenges of a rapid urbanization, mega-cities and densified urban areas cadastral system must include the third and fourth dimension not for cadastre and buildings only but for the entire core spatial data infrastructure. The development of systems outside of the SDI showed that they reached a suitable level for the applicability of 3D and 4D data.

2.5.3 Consequences

The 3D component and the temporal aspect shall not be regarded as extension of the 2D-based SDI. A paradigm shift in the design of SII is needed. The legal base and technical aspects like application schema, business logic and presentation must be redesigned to provide more encompassing information about each feature. The principles and paradigms of cadastral system like conceptual data models (data centric model), thematic independence and object orientation must be maintained in order to minimise complexity of 3D-based topological validation rules and to not split one real-world object (tunnel) into a large number of parts because of intersecting parcels.
The temporal component is less complex to solve since its applicability has been proven in many application. In the aviation information domain every object has a complete documentation about the entire lifecycle and future changes can also be treated. When a phenomenon disappears or ends its representation in the database is not deleted but marked as withdrawn or inactive. All relevant changes to a phenomenon are time stamped in order to show the evolution over time (cf. www.aixm.aero). If the cadastral agencies make no significant progress towards true 3D and 4D in near future it is expected that other organization will step in, allocate the funds and provide information to the citizen and administrative organization they require nowadays.

2.6 Handling distributed responsibilities

Thesis 6: Distributed responsibilities are a fact and will not decrease. It's more productive building an infrastructure to handle this in an effective way, than changing grown structures.

2.6.1 Explanation

Different political systems, technical limitations and organizational traditions lead to distributed responsibilities. The division of such responsibilities does not follow strict rules but can vary fundamentally: states with strong centralism have different needs compared to federal states with distributed responsibilities. Purely governmental bodies require other solutions compared with privately or mixed run (public-private-partnership) organization. Too much energy is wasted for fitting the historical and grown structures to technical systems. Recent technical developments like web-oriented architecture are perfectly suited to adapt to such different organization forms and eventually overcome barriers. The data integration concepts as discussed in Thesis 2 do not depend on organization structures and can also adapt to different configurations by design.

2.6.2 Rational

In very rare cases the responsibility and competency for a complete representation of a real world phenomenon is unified in one organizational body. Due to different roles (e. g. object owner, regulatory authority, technical competence centres) the collection, maintenance, control or approval of data items are spread over several bodies. Also within technical competence centres (like SDI-providers) the responsibility for the development of products, specific analysis, data extraction and publications may be spilt. Organisational structures have often been inflexible because of limited knowledge within the organisation and dependencies from single specialist. With growing technical interoperability, open information architecture, approximation of spatial information systems to general information systems and immense knowledge repository in the web the dependency from single actors will diminish. SII can therefore become easier adoptable to varying structures.
Within the SII the distributed responsibility are for all three tiers of major importance. With respect to the data storage layer the location where data is stored should not play a role (expect if legally restricted). Data may be organized according to geographical, thematic or organisational aspects. The data storage has to provide the abstracted data access through web-services and controls the security. The application logic layer controls the business rules but again does not necessarily be combined with the data storage layer. Hence the same business rules can be used for the operation on the same thematic data which may be stored according to geographical coverage at different locations. In the presentation layer the different user demands must be supported by a flexible adaption of application functionality, data combination (mash-ups), data granularity (provided level of detail) and presentation. It must be made sure, that for all components (data, algorithms, infrastructures, security or services) the responsibility is defined and agreed upon and that all actors are aware of.
Such architecture provides a versatile framework so that data collection, maintenance and use on the same data source can be consistent across different organisations. At the same time it does not require building a "Swiss Army Knife" application but more a collection of applications with different functions which can interact. With this flexibility an efficient information infrastructure for varying organisational structures can be built up. It is adaptable for change processes (form follows function) without guiding structures actively. The huge work load for change processes (with often unpredictable outcome) will thereby not be triggered or driven by technologies any more.

2.6.3 Consequences

For the implementation of a distributed infrastructure following precondition must be met:

1. Open attitude and the intention of the parties, to taking the advantages of distributed responsibilities seriously.
2. Open system architecture based on web-services and clear separation between data

storage, application logic and presentation layer (tiers).
3. Systematic and standardized coupling of application parts and well defined interfaces between the tiers.
4. High-performance network infrastructures (band-with, latency).
5. Ensure, that the SII in its entirety does not contain gaps in the responsibility.

3. CONCLUSION

With the anticipated growing penetration of spatial data in the society and the increasing number of smart phone apps using mapping and localization service it can be expected, that the spatial information will follow the "ubiquitous computing" and become permanently present. It is expected that the demand for more and "better" (spatial) information will increase. Whilst crowd sourcing has proved playing an important role for some users and applications it will be up to the spatial information community to anticipate future needs and trends.

Developers and providers of spatially enhanced apps will integrate the best available data at no cost in their products. For some data sets (like OpenStreetMaps) and for some areas the differentiation of the quality between official cadastral data (high reliability but sometimes poor timeliness) and crowed sourced data (unclear reliability but partially high update frequency) is difficult. For end users inconsistencies between different data sets for whatever reason are unacceptable. The public agencies must be aware that the provision of governmental data offers more changes and benefits than disadvantages. The legal, technical and organisational base for a next generation SDI must be tackled to valuing the investments in spatial data.

The cadastral community should actively influence the transformation processes and take over a pioneer role for SII: Cadastral organisation built a huge knowledge and practical experiences on handling spatial data. Compared to other spatial data the legal base for cadastral data is much better. Last but not least cadastral data have relevance as reference data set for many other spatial data sets and as localisation source for textual data which are linked to parcels, buildings or addresses.

REFERENCES

Goodchild, M. F. (2007). Citizens as sensors: The world of volunteered geography, GeoJournal 2007, 4, p. 211-221.

GSMA Intelligence (2015),The Mobile Economy 2015. 82p, http://www.gsmamobileeconomy.com/GSMA_Global_Mobile_Economy_Report_2015.pdf (accessed 01/03/2015)

EUROCONTROL (2007), Final Report for the Draft implementing rule on aeronautical data and information quality, Edition 2.0, 16 October 2007, 237 p. – http://www.eurocontrol.int/sites/default/files/article/content/documents/single-sky/mandates/20071016-adq-final-report-v2.pdf (accessed 02/02/2015)

Harvey, F., Kuhn, W., Pundt, H., Bishr, Y., & Riedemann, C. (1999). Semantic interoperability: A central issue for sharing geographic information. The Annals of Regional Science, 33(2), 213-232.

Hofer, S., Haring P., Schaller C. and Lüthy J. Infrastructure management in Swiss municipalities - Development of a modern, spatially enabled management cockpit Paper Sofia 2015

Jetzek, T.; Avital, M. and Bjorn-Andersen N. (2013), Data-Driven Innovation through Open Government Data. J. theor. appl. electron. commer. res. [online]. 2014, vol.9, n.2, pp. 100-120. ISSN 0718-1876. http://dx.doi.org/10.4067/S0718-18762014000200008., last accessed 03/01/2015

Karki S., Thompson R. and McDougall K. (2013). Development of validation rules to support digital lodgement of 3D cadastral plans In: Computers, Environment and Urban Systems, Volume 37, 2013, 12 p.

Kaufmann, J. and Steudler, D. (1998). Cadastre 2014 – A Vision for a Future Cadastral System, with working group 7.1 FIG Commission 7, 51p.

Kaufmann, J. (2010). The New Swiss Law on Geoinformation and the Ordinance on the Cadastre on Public Law Restrictions (4064), FIG Congress 2010, Sydney, Australia, 11-16 April

Kaufmann J. and Steudler D. (2012) Common Data Integration Concept. In Steudler D. and Rajabifard A. (Editors). Spatially Enabled Society, FIG Report 58

Lüthy J. (2014). An integration platform for a spatially enabled society. in D Steudler (ed.), CADASTRE 2014 and Beyond. vol. 61, FIG Denmark, Copenhagen, pp. 43-48.

Müller H. and Würriehausen F. (2014). Crossborder Interoperability of Land-Use Information, FIG Congress 2014 (7332), Kuala Lumpur, Malaysia, 16 – 21 June

Phillips, A., Williamson, I. and Ezigbalike C. (1999). Spatial Data Infrastructure Concepts. The Australian Surveyor, 44(1), 20-28.

Reid, K. (2008). Towards a Common Understanding –Creating the Network-centric Environment, "From AIS to AIM", Presentation at the ICAO Worldwide Symposium on Enabling the Net-Centric Information Environment 2008, 17 p. – http://www.icao.int/safety/information-management/Transition%20Library%20for%20AIM/Documentation/Towards%20a%20Common%20Understanding%20Creating%20the%20Network-centric%20Environment%20-%20From%20AIS%20to%20AIM.pdf (accessed 02/02/2015)

Rajabifard, A. and Box, P. (2009). SDI Governance: To Steer or Row. GIM International, Vol. 23 (2). <www.gim-international.com/issues/articles/id1276-SDI_Governance_to_Steer_or_Row.html>, (accessed 02/02/2015).

Steudler D. and A. Rajabifard (Editors, 2012). Spatially Enabled Society, FIG Report 58

Van Oosterom, P. J. M., Stoter, J. E., Ploeger, H. D., Lemmen, C., Thompson, R., & Karki, S. (2014). Initial analysis of the second FIG 3D cadastres questionnaire: status in 2014 and expectations for 2018. In Proceedings 4th International FIG 3D Cadastre Workshop, Dubai (United Arab Emirates), 9-11 Nov., 2014. International Federation of Surveyors (FIG).

Vučić, N., Roić, M., & Markovinović, D. (2014). Towards 3D and 4D Cadastre in Croatia. In 4th International FIG 3D Cadastre Workshop.

BIOGRAPHICAL NOTES

Jürg H. Lüthy is member of the Management Board at SWR Geomatik AG, one of the largest geomatics companies in Switzerland. He obtained a master's degree in 1996 from Federal Institute of Technology Zurich (Switzerland) in Rural Engineering and Survey. From the same institution he holds a PhD (2007). He has many years of experience in spatial data management, transition from paper maps to data centric systems and the operation of Spatial Data Infrastructures. His current focus lies in the provision of holistic information using modern web-technologies like building the technical infrastructure for Cadastre of Public-law Restrictions on landownership. He is the Swiss delegate to FIG Commission 3.

Christian Kaul is head of Department for Geoinformation at the Office for Spatial Development in Canton of Zurich (Switzerland). He obtained a master's degree in 1992 from Federal Institute of Technology Zurich (Switzerland) in Rural Engineering and Survey. After ten years of experience in different domains like communal infrastructure, land management and SDI-Projects he worked a consultant in cadastral issues and procurement processes. Back in an engineering company he completed his experience in land use planning and spatial development. Since 2013 he focuses as head for Department on building modern cadastre systems and holistic spatial information infrastructure.

CONTACTS

Jürg H. Lüthy
SWR Geomatik AG
Wagistrasse 6
8952 Schlieren
SWITZERLAND
Tel. +41 43 500 44 48
Email: juerg.luethy@swr-geomatik.ch
Web site: www.swr-geomatik.ch

Christian Kaul
Office for Spatial Development
Canton of Zurich
Stampfenbachstrasse 12
CH-8090 Zürich
SWITZERLAND
Tel. +41 43 259 27 67
Email: christian.kaul@bd.zh.ch
Web site: www.are.zh.ch