Quality Management for cadastral Systems

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SUMMARY

Cadastral systems are a 'System of Record' and represent both the legal and the physical world. Many cadastral agencies, which are the authoritative source for cadastral information by law, suffer from severe quality issues, often to an unknown extent. Data quality is not uniform and is usually directly related to how the data was collected, assembled, and maintained over many years. Ignorance is not a bliss: poor data quality causes undesired consequences such as loss of trust, poor decision making, and other agencies creating their own competing trusted versions of the cadastral data. With the right tools and technology, the cadastral data can be evaluated, quantified and dedicated tools can be used to fix common errors. Common quality issues range from missing and wrong attribution, geometry related issues such as topological integrity problems and poor spatial accuracy and suspicious measurements in the survey network. The diversity in business requirements, priorities of issues and the workflows to address them varies greatly between different organizations. This requires easy configuration to meet the unique business needs of every cadastral organization. Issues, often modeled as error objects, must be stored and communicated in efficient manner. The parcel fabric ships with built in quality management rules that can be configured to meet the unique business needs. Important quality indicators are stored as metadata on the relevant cadastral features. Real world examples of common quality issues are used and demonstrate different engines and capabilities to assess and fix them. Best practices used to gain stakeholder and public trust are examined. Since cadastral data is a foundational dataset for many other datasets like zonings and administrative boundaries, quality improvements to the cadastral data should also be applied to the dependent datasets.

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1. IMPORTANCE OF QUALITY IN A 'SYSTEM OF RECORD'

Cadastral systems are first and foremost a 'system of record' that store authoritative datasets that are used by many different stakeholders. Most of the cadastral agencies are mandated by law to maintain and manage cadastral data and see themselves as the sole provider of the data. The importance of a well-functioning cadastral systems extends beyond the cadastral community and is a contributing factor to the national economy. In Norway (Leikney 2017) most real properties can be found by searching for the cadastral number in the cadastre, but this tells us nothing about the quality of the boundaries. Cadastral agencies are legally trusted to maintain cadastral data, but do they consider cadastral data as a product? Do they have the tools to evaluate the quality of data?

What are the top five major consequence of poor-quality data (of any kind)?

- Poor decision making
- Business inefficiencies
- Mistrust
- Missed opportunities
- Lost revenue

These 5 consequences are applicable to cadastral data as well and in many countries, cadastral data of poor quality can no longer be trusted. In places in which cadastral transaction are public, stakeholders mistrust drives them to manage and maintain their own trusted version.

2. QUALITY & FIT FOR PURPOSE (FFP)

One of the challenges in designing a cadastral system is the diversity in requirements. Each agency has their own legal framework, dataflows and business requirements. Designing a 'one fit all' system is therefore impossible, and many customers chose to custom build their own quality assurance checks. A custom 'tailor made' system might be great at first but becomes stale when new surveying technics, data sources, and requirements change over time. Time also has to be accounted for when design a 'Fit For Purpose' system because 'purpose' changes over time.
Quality is modeled using object oriented 'parcel behavior'. Where the term 'parcel' is used in the broader sense and can represent and of the 3 'RRR' (Rights, Restrictions, Responsibilities). Quality is part of a parcel behavior and is modeled using a framework of rules. At any point of time, the rules can be evaluated to either generate error features or

prevent bad data from being created. For a system to be successful such rules must be easily configurable by subject matter experts.
The fitting process in a Fit For Purpose system must not that is based in customization tends to be expensive in the short and long run. 'Customized systems' are often outdated by the time they are implemented and become stale due to the high cost of keeping current with emerging technologies and business requirements. 'Configurable systems' on the other hand, do not require developers and can be easily upgrades and configured to 'fit for purpose' at any given time.

3. QUALITY AND CONCEPTUAL INFORMATION STANDARDS

Industry standards such as the Land Administration Domain Model (LADM) and the Social Tenure Data Model (STDM) are conceptual information models. They do not include the conceptual rules and the error features that govern the parcel behavior and quality. All cadastral system, regardless of their purpose, maturity and complexity need to take quality into consideration: rules, error features and feature level quality metadata.

4. DETECTION OF TOPOLOGICAL ISSUES

In GIS, Topology is defined as the spatial relationships between adjacent or neighboring features. A geodatabase topology provides a robust way of defining topological relationships among spatial features. The flexibility to configure topology rules for features in the cadastral data, allows one to validate and assess the data quality at any point of time. Errors are features that can be displayed and shared on any type of client (desktop, web) to communicate violation of the configured rules. Common rules include: Parcel boundary lines must be covered by a parcel polygon (and vice versa), The end points of boundary lines must be covered by a point, Boundary lines must not self-intersect and must not have dangles, and parcel polygon must not overlap. After detecting the errors using a variety of tools such as the Error Inspector, the user has the discretion to use a predefined fix method that is associated to that specific error type.

5. DETECTION OF BAD ATTRIBUTION

Cadastral features have many attributes. Common parcel attributes include a unique name, legal area and reference to the cadastral framework location which in many cases is based on administrative boundaries. Common parcel boundary attributes include the recorded (COGO) measurements and spatial accuracy estimate. Common parcel point attributes include coordinates, accuracy estimates and physical description. Attribute Rules is a new framework for calculating, constraining and validating rules. Data that can be automatically calculated based on intersection with administrative boundaries improve efficiency and prevents human errors, constrain rules prevent bad data from being saved in the systems and validation rules evaluate the data regardless of when and where it was created. It can be used to make sure that the parcel name adheres to the business rules and unique for example. Another advantage of the attribute rules framework is that it can access both the alphanumeric attributes as well as the geometry. This capability allows the legal area to be compared to the geometry based (shape) area, the recorded distance and direction to be compared with the geometry and so forth. Any errors can be visualized and shared on desktop, mobile and web clients. [Parcel fabric Attribute Rules] can be imported and configured to match business requirements.

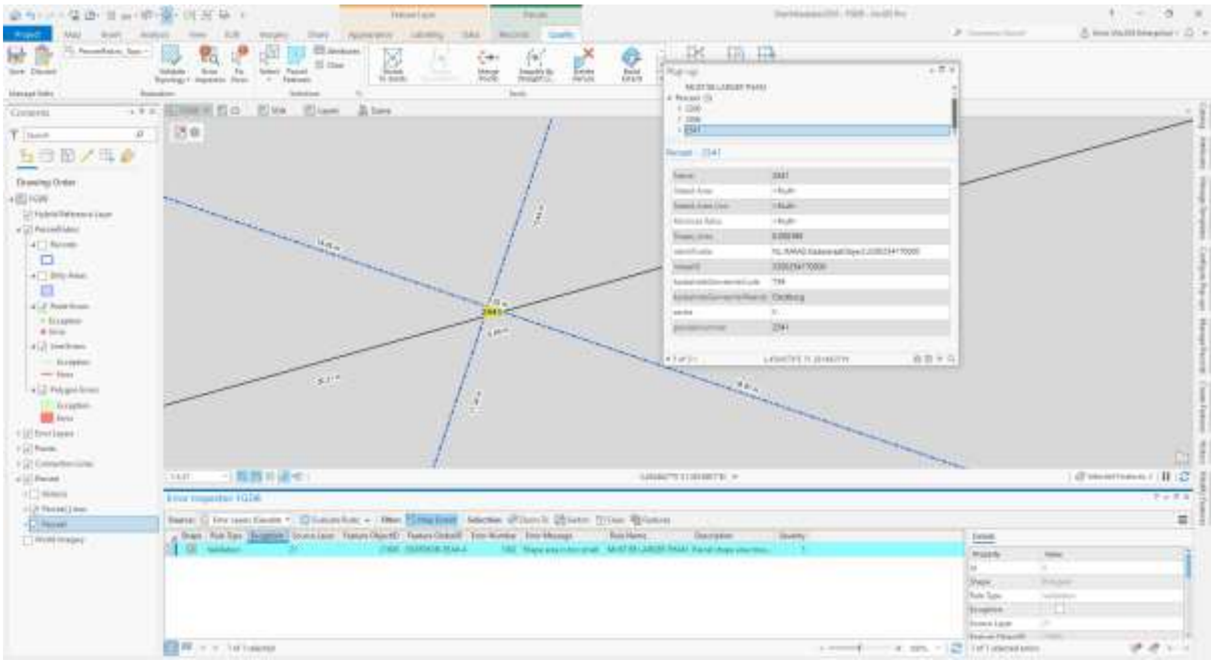

Figure 1: Attribute rules validation detects issues that can be viewed in the Error Inspector. In this example: a very small 'parcel' (data curtesy of open data by Dutch Kadaster DKK)

6. DETECTION OF OUTLIERS AND EVALUATION OF SPATIAL ACCURACY

Cadastral systems combine data from different sources that were sometimes collected and recorded in past decades and even centuries.
Using the DynAdjust Least Squares Engine (LSA) and free network adjustment, every newly submitted survey plan can be checked for consistency to detect outliers. Outliers in coordinates, distance and direction are visualized using dedicated analysis layers and the power of GIS visualization.
Once the individual survey plan passes the consistency check, it is combined with the legacy data and a constrained and weighted LSA can help evaluate and improve the spatial accuracy. Beyond the common error ellipses, GIS advanced visualization technics can be applied to any of the attributes to generate a meaningful map like a spatial accuracy 'heatmap'.

This process can be automated to occur when a new survey plan is submitted and/or a control point coordinate is updated. Knowing the estimated spatial accuracy on a national basis helps decision making.
'One of the biggest advantages using the processing method of least squares is that all measurements can be analyzed simultaneously.' (Badea, 2014)

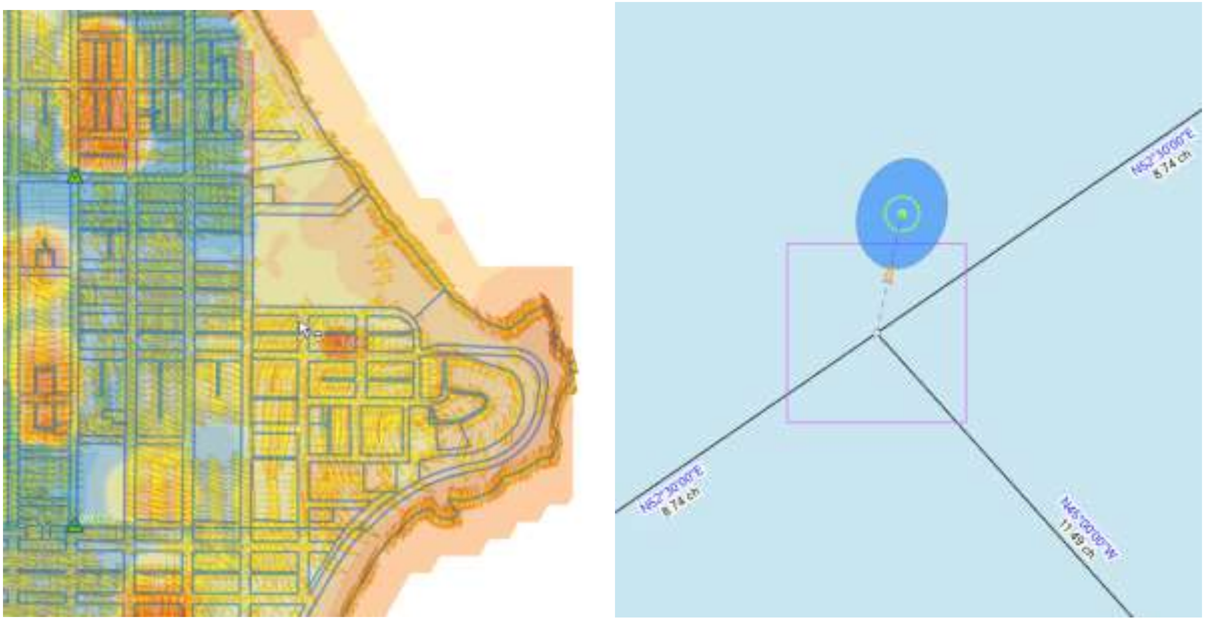

Figure 2: ArcGIS Pro advanced visualizations can be used to visualize LSA results such as Spatial Accuracy Heatmaps, error ellipses and outliers. (Data curtesy of Sheboygan County Wisconsin)

7. SCALABILITY AND EXTENDIBILITY

Cadastral systems are often distributed across multiple physical sites. The system must be performant with regards to quality checks. Using Service Oriented Architecture (SOA), server resources can be leverage to empower thin clients, and additional computing resources dynamically adjusted to deliver great performance. Other technics to improve distributed performance include the use of cloud Kubernetes orchestration, client side and server side caching, and ability to scale the system by adding additional resources as needed.
'Fit For Purpose' (FFP) does not mean inferior quality. It means that the quality level meets the purpose. The principal of FFP is also applicable for any national dataset: not all parcels have to meet the same spatial accuracy standards, for example.
Extendibility of the system with relate to quality is the ability to modify the parcel behavior, in terms of geometry, attribution and survey measurements over time. The rules that model parcel behavior are part of the physical information model. This means that the rules can be adhered to regardless of the type of client (desktop, web, mobile) that connects to it.

8. IMPROVING DEPENDENT DATASETS

Cadastral datasets are a foundational dataset for every NSDI. Other datasets such as land use, administrative boundaries as well as cartographic annotations are correlated to parcel geometry. Every process that causes cadastral data to move creates misalignment with the dependent dataset. Such processes include running a weighted and constrained least squares adjustment, integrating new measurements and quality improvements. Another challenge is that those dependent datasets are often managed by other organizations that are forced to consume the authoritative cadastral representations. Using the temporal nature of parcel fabrics, points that moved between 2 moments in time can be identified and links are generated. These links are used to adjust the related datasets, keep their in alignment and improve their spatial accuracy.

9. QUALITY CONTROL PROCESS

Once quality standards have been defined and rules configured, the quality processes have to be defined. Many cadastral organizations lack well defined workflows and metrics for the QA-QC processes. Often it is left to the individual to decide which tools and to which extent they scrutinize received data, and whether or not it will be reviewed by another person before being checked into the production system. In a multiuser editing environment, versioning should be used to allow multi-user editing and the ability to transfer a “job” between one person to the other. Roles and privileges have to be defined, clear quality metrics, and a repeatable workflow that represents the best practice for each job type. The level of quality checks should not be dependent on the person ingesting the incoming data.
Systematics data checks should be defined to assess the data quality. With a clear view of the quality issues and their business impact, a plan to improve the data can be initiated.

10. CONCLUSIONS

Quality is the backbone of any system of record and its importance for cadastral data is magnified as it is used as a foundation to other datasets. The diversity between cadastral datasets and organizations dictates that quality should have a configurable framework to define the desired parcel behavior using rules. The rules should ‘Fit To Purpose’ and be, like metadata, part of the information model. Using Service Oriented Architecture, web services can be used from any type of client (web, desktop, mobile) to validate the data and generate error features. Quality processes that promote best practices in a multiuser editing environment should be defined to guarantee a consistent level of product. Improvements in the spatial accuracy of cadastral data should also be applied to dependent datasets to maintain coincidence. The new generation of the Parcel Fabric is designed to meet the business requirements for the next 15-20 years and ships with configurable quality framework.

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BIOGRAPHICAL NOTES

Amir Bar-Maor graduated with a degree in geodesy from the Technion – Israel Institute of technology in 1999 and a master degree in geodesy in 2002. After working for several years designing and implementing GIS technology, he joined esri in 2008 – initially as a project manager and consultant for cadastral projects and later as a product engineer in software development. Amir is a licensed cadastral surveyor and a licensed real estate appraiser.

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