Parcel Fabric 2.0 - Fit for (Multi) Purpose

Amir BAR-MAOR, the Netherlands

Key words: FFP, Parcel Fabric, Cadastre 2034, LADM

SUMMARY

Cadastral systems and organizations are faced with multiple, diverse set of challenges. With the development of the next generation of parcel fabrics, current business requirements as well as future anticipated requirements (i.e. Cadastre 2034) were taken into consideration. A team of highly skilled and experienced experts spent more than 40 man-years designing and building the next generation of parcel fabrics that will serve many nations for the next 15-20 years. Working closely with worldwide experts and leading organizations helped defined the challenges that must be overcome. Parcel Fabric 2.0 is based on LADM (ISO 19152), Fit for Purpose (FFP), best Practices, 3D Cadastre and Cadastre 2034 strategies as well as decades of experience. Parcel Fabric 2.0 is driven by real world business requirements and detailed workflows (use cases). This paper outlines common challenges faced by mature and developing cadastral organizations, demonstrates how the new parcel fabric solves them and can assist cadastral organizations to meet their future aspirations.

Parcel Fabric 2.0 - Fit for (Multi) Purpose

Amir BAR-MAOR, the Netherlands

1. INUSTRY CHALLENGES

Cadastral systems and organizations are faced with multiple, diverse set of challenges. Unique requirements and constraints have led to the successful development of ‘Fit For Purpose’ (FFP) approach (Stig Enemark et al 2014). However, when designing scalable and robust software that meets the diversity in the cadastral industry one has to first identify the common challenges cadastral agencies are faced with:

.1.1 Data

Most agencies have poor quality management practices and tools. Without the metrics and the spatial intelligence, the agencies are unable to assess the quality of their data based on their business rules. Common issues include topological integrity issues such as overlaps and gaps for parcel types that should be continuous and seamless, attribution errors for parcel as well as measurements. Often there is lack of accountability as user identity and edits are not tracked and are not tied to the legal source documentation from which they were created. While the data is being collected with high accuracy in the field, it is often degraded to fit regulations: the spatial accuracy is reduced by inversing measurements between collected points and the point’s accuracy metadata is lost. Other common challenges include fragmented digital data that is stored as discrete files in multiple formats, often on users’ computers. The lack of a central location for the most current data often causes users to keep their own version ‘their’ files and makes it impossible to publish a current authoritative data. The issues stated above causes stakeholders to lose their trust in the data for decision making and often even create their own competing version of the same data.

.1.2 Workforce

Many cadastral agencies report of aging workforce on one hand and a challenge to recruit and retain new younger workforce on the other hand. A long learning curve for new employees is often caused by lack of best practice and common tools. Even if best practices do exist they cannot be enforced and tracked. While the industry is quick to adopt the latest generation of a GNSS receiver, LIDAR scanner and drones, it is often very conservative when it comes to the symbology of the cadastral map. Many cadastral maps could be easily become more cartographically appealing and readable by introducing color and making them accessible over the web with the appropriate symbology for their purpose. While some organization embraced the concept of a seamless digital cadastral map, some are still using GIS tools as a replacement for their CAD drafting tools on a map by map basis.

.1.3 Efficiency

Many cadastral agencies have some of the following inefficiencies:

.1.3.1 Reverse engineering hardcopies

Some agencies still accept hard copies of maps. No only do they have to scan and archive them, they are still using the printed map to create parcel geometries by either digitizing them or entering the measurements.

.1.3.2 Redundant data entry in multiple systems

A legal transaction that redefines a parcel geometry usually involve multiple systems such as a land registration system, mass evaluation system, document management system, financial system and other where similar and even the same data is entered multiple times.

.1.3.3 Manual Quality Checks

Most organizations have not automated their quality control checks

.1.3.4 Processes that rely on multiple tools and file formats

When processes rely on multiple software packages and file formats any automation attempt will require additional effort in integration, data interoperability to switch formats and a long learning curve. Such integration often creates dependency between systems, resulting in stagnation.

.1.3.5 Lack of workflow management tools

Without modern configurable workflow management tools it is a challenge to manage resource efficiently for both office and field work. Lack of KPIs and dashboard help monitor progress and identify bottlenecks. Such data also in planning and prediction. It is hard to achieve productivity related SLAs when metrics are not collected and cannot be visualized.

.1.3.6 From raw data to information products

Data must be readily available as information products that meets a stakeholder need. Instead of supplying raw “open data” in a format that requires experts to interpret and special tools to read, stakeholders expect focused maps and apps on the web browser and mobile device that excel in meeting a well-defined business need. Instead of a document of UML diagrams stakeholders prefer storyboards and short videos that explain how to use the information product.

.1.4 Analytics

Parcel are not only a system of record but also a system of insight. Most agencies, even those that use least squares adjustment, do not have an accuracy heatmap for their parcels. The level of reliability of the data is also questionable and lacks indicators (feature level metadata) as for internal, absolute and attribute reliability. Changing demographics and predicted hotspots of parcel activity can also influence decision makers when it comes to planning and resource allocation. Beyond the analytical capabilities agencies often lack the dashboards and visualizations that can provide them the insights needed internally as well as by external stakeholders for tenure and evaluation.

.1.5 Stakeholder Engagement

Agencies that do not engage their stakeholders to understand the needs, internally and externally, might become irrelevant in the eyes of the tax payer and potentially replaced by the private sector. With ever changing technology people expect to be able to access current data from any device and get the information they need in a secure manner. When agencies lack to collaborate with their stakeholders (such as: public, notaries, surveyors, other government agencies) will find it challenging to create a sense of community and get recognized for their achievements.

.1.6 Legal Constraints

While technology changes fast and easily adopted, legislation will always fall behind and is slow to adapt. In some countries, surveyors use GNSS to capture parcel turning points and then use them to inversed line measurements and use them for legal descriptions although those lines were never observed. When inversing and printing paper maps for submission, the spatial accuracy is often degraded, and the precious accuracy metadata is lost. While our notion of the parcel physical boundaries keeps changing and improving over time, the legal representation of the parcels needs to be stored as it was recorded in a ‘System of Record’. Ideally these two representations can co-exist in the same dataset and without introducing a future and never-ending conflation project. Many cadastral systems need to support a variety of land descriptions and tools to capture them such as metes and bounds, coordinated based cadastre and 3D cadastre. The latter, 3D cadastre, introduces additional legal challenges (Jantien Storer et al 2013).

.1.7 Technology

Highly customized systems take years to implement and are usually out of date when deployed in the production system. Old and customized systems are usually expensive as they are hard to maintain, make it difficult to recruit and train new workforce, lack modern capabilities and interoperability, are restrictive in terms of integration to other business systems and lack adequate technical support.

Even when using COTS technology, some organizations use old software that is no longer supported, many times due to old client-server integration. Beyond no longer being supported, old software can create security risks as they often restrict the organization to use very old operating systems.

2. PARCEL FABRIC 2.0 DRIVERS

2.1. Simple, efficient, easy to adopt

Parcel Fabric 2.0 must be easy to adopt for all organizations.

- **Data**: any parcel data should be easily migrated regardless of legacy issues. Once migrated it should allow organizations to decide if, when and how they wish to address any data issues.
- **Adoption**: learning curve should be reduced by providing great defaults. Parcel Fabric 2.0 should ship with common repeatable workflows as tasks. Tasks are used to define best practices, improve efficiency and make users productive from day one. Users should not be restricted to using special parcel toolsets.
- **Administrators** should be able to configure maps, layers, tasks, validation rules, permissions without any development efforts.

2.2. Quality: Prevent, Detect, Fix

Quality is an important pillar in any ‘System of Record’. Furthermore, the definition of a ‘bad parcel’ is different between jurisdictions, parcel types (e.g. rights versus easements) and can even change over time. Administrators should be able to easily configure the desired parcel behavior using rule engines. Such rule engines can prevent bad data from being created and validate existing and submitted data. Rules should apply to both geometrical topology as well as attribution of parcels, boundaries and points. When rules are violated error features should be created. Error features should be visualized on any type of client: desktop, web browsers and mobile devices and shared in real time using services in a variety of open formats.

2.3. Performance and Scalability

Parcel Fabric 2.0 should be always performant and able to scale from a few hundred parcels to a few hundred million parcels in a variety of spatial references. Large system should be ‘low maintenance’ with the option to host servers on cloud infrastructure to reduce cost. It should support common and proved DBMS platforms that can scale, track user identity and support 4D.

2.4. Service Oriented Architecture

Parcel Fabric 2.0 should support service oriented architecture (SOA) for both data and common parcel functionality. SOA makes current data secure and accessible on any device at any time and anywhere. Services should be used to integrate between business systems and reduce the long term maintenance and dependency between business systems. GIS services can also geo-enable business system by exposing the right map and tools for a given use-case. Administrators should be able to manage permissions on a given service as well as exposed capabilities. This means that once a named desktop user saves their edits to the published versioned of the data, the read only read only public facing web map reflects the update instantaneously: no need for ETL process and all stakeholder can trust the data for decision makers.
Services also expose method through use of REST API. With REST API desktop, web and mobile apps can be developed while sharing common behavior regardless of the client type – ‘Fit to Purpose’ is also applicable in the app context: choose the right tool against the REST API.

2.5. Automation

Automation increases efficiency and quality. Parcel Fabric 2.0 automation are achieved on a few different tiers:
ArcGIS Pro Tasks: Tasks are designed for repeatable workflows. Beyond providing the user with ‘the right tool in the right time’ they also control variety of project, map and layer settings which reduces mouse clicks.
REST API get be used to geo-enable business systems. A parcel merge for example, does not require any map interaction and be accomplished by providing the parcel fabric merge REST API method with the parent parcels through services. The REST API is also exposed as a Python module to allow automation through Python scripting.
Geoprocessing framework can be used to create geoprocessing models or python scripts. Example of automation using geoprocessing include the processing of a digital submission, BIM model, creating points and updating parcel corners using coordinates in a text file and much more.

2.6. Integration to Business Systems

Cadastral systems are never a single system but more often a conglomerate of business systems such as a GIS system, land registration system, document management system, ERP system or financial system, computer assisted mass appraisal system (CAMA), addressing, planning and others. A good integration between systems eliminates redundant data entry, improve quality and leverages the added value of each system. The GIS system can provide the spatial intelligence and used as a central point of entry.

2.7. Parcel Lineage and Historic Parcels

Cadastral data must be defendable. In Parcel Fabric 2.0 all cadastral features are associated to recorded reference in a feature class called 'Records'. The records are the footprint of the legal transactions and their geometry gets updated automatically making it easy to discover all the legal transactions in a given location. As parent parcels get retired they are flagged as historic parcels and are not deleted. Parcel Fabric 2.0 determine and tracks which record retired each parcel polygon, boundary line and point. The parcel lineage is tracked and maintained automatically as parent parcels get merged and split. When boundary lines are split, the newly created boundaries also track the boundary from which they were created. (Pieter Soffers and Eric Hagemans 2017).

2.8. 2D, 3D & 4D Cadastre

Parcel fabric 2.0 supports 2D and 3D parcels. With Branch Versioning, the fourth time dimension allows to compare any 2 moments in time and get access to the geometry and attributes of any feature as they existed in that historical moment.
All Parcel fabric 2.0 are Z aware and support true curves, but visualizing data in 3D can be easily achieved and maintained even with 2D geometries. Using attribute driven approach to define elevation and extrusion prevents building from floating or penetrating the elevation surface when the elevation model is updated and/or when building and ground sink. However, Parcel Fabric can also consume real 3D geometries including from BIM models. Parcel Fabric 2.0 provides a 'continuum of 3D' capabilities as 3D data collection is expensive (Moshen Kalantari et al, 2018; Jantien Storer et al 2013).

2.9. Digital Submission

More and more cadastral agencies become more efficient by creating a digital submission standard, usually in CAD or a special non-graphical file formats. Parcel Fabric 2.0 needs to allow submitters not only to provide their data but also validate it against the configured business rules and see errors visually on the map. Some agencies aspire to have the submitter take care of alignment with surrounding legacy parcels. The use of services for parcels, validation and versioning is in line with such aspirations.

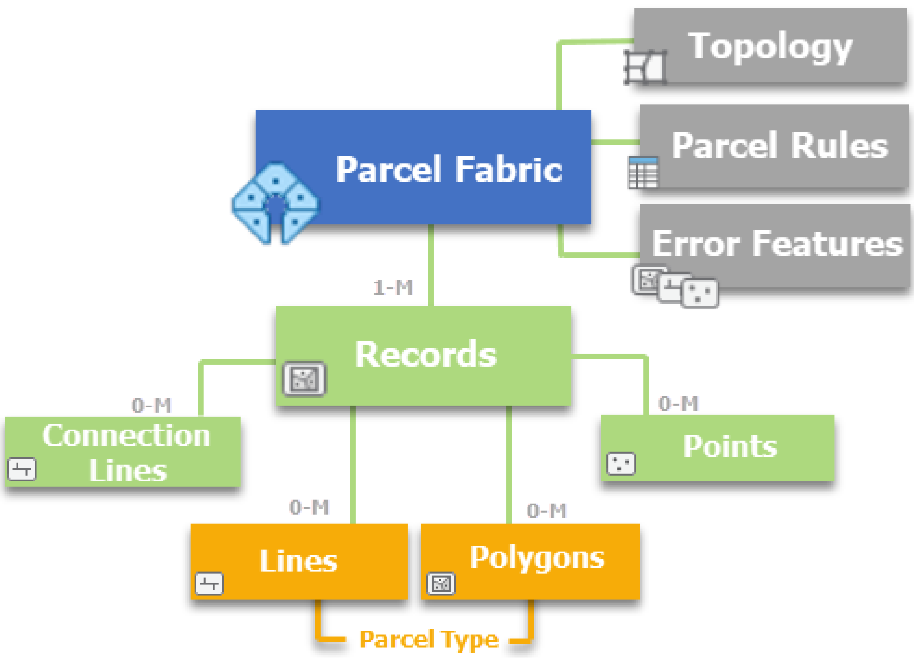
2.10. Coordinate Based Cadastre

Parcel Fabric 2.0 needs to support coordinate based cadastre from mobile devices and ruggedized laptops in a connected and disconnected mode. Using high accuracy GNSS receivers, boundaries and points can be created and updated while saving accuracy metadata. Quality assurance is pushed to the field to reduce round trips, when connected to the network, the server can be used to run Least Squares Adjustment (LSA) and help evaluate if the desired spatial accuracy has been achieved before returning from the field.

3. PARCEL FABRIC 2.0 INFORMATION MODEL

The Parcel Fabric is a controller dataset that that controls the following feature classes and topology:

- Parcel type feature classes
- Geodatabase topology
- Records feature class
- Connections feature class
- Points feature class



3.1. Records feature class

Parcel data is recorded on legal records such as plans, plats, deeds, and records of survey. The parcel fabric is a records-driven system, and parcel features are associated with the legal record that created them.

The Records feature class stores information about the legal parcel record such as the record date and record type. All parcels, boundaries, points and connection lines are associated to the record that created them as well as the record that retired them. The record feature is a polygon feature that is the footprint of the cumulative parcel geometry of all the parcels associated with it.

3.2. Parcel type feature classes

Parcels are added to the parcel fabric as parcel types. A parcel type is comprised of a polygon and line feature class and is defined by your organization. You can add as many parcel types as necessary for your organization. A parcel type is defined by a separate polygon and line feature class, and both parcel polygons and lines are associated with the legal record that created them. Parcel types can have different schemas (attribute fields and related tables) and can participate in different geodatabase topology rules and attribute rules. A parcel type can also be set as 'Administrative' parcel to support very large parcels. Parcels can have true parametric curves, natural boundaries, holes (donut shape) and be a multipart geometry, in 2D and 3D.

The parcel fabric boundary model supports a single shared boundary between 2 adjacent parcels. If needed, overlapping boundaries can be added, to meet business requirements.

The parcel fabric can be easily mapped to the conceptual Land Administration Domain Model (ISO 19152). Extending the physical information model with additional tables and relationship classes is easy to configure and DBMS agnostic

3.3. Connection Lines feature class

Connection lines are used to define measurements between points that are not parcel boundaries. For example, connection lines are lines that connect parcel points across roads, define a road centerline or lines that connect parcel points to control points. Connection lines also densify the survey network for least squares adjustment.

3.4. Points feature class

Points represent parcel corners, end points of connection lines, and stand-alone cadastral reference features such as control points. When a parcel point location is updated, all the boundaries and parcels that are connected to it will be updated as well to prevent slivers and gaps.

3.5. <u>Geodatabase Topology</u>

The parcel fabric controls a geodatabase topology that is used to define and configure topological rules. Topology is the arrangement that defines how point, line, and polygon features share coincident geometry. Topology rules can be extended as needed with additional rules for specific parcel types, parcel subtypes and even feature classes that are not controlled by the parcel fabric. At any point of time, and usually data modification, the topology can be validated. Any violation will create error features.

4. PARCEL FABRIC 2.0 WORKFLOWS

An information model is not of much use if it does not provide the tools and the workflows required to properly maintain the information. There are 2 types of workflows that can be applied to parcels: ‘Record Driven’ workflows and ‘Quality Driven’ workflows.

4.1. <u>Record Driven Workflows</u>

‘Record Driven’ workflows are usually triggered by a recordation event. Usually such an event, like a parcel merge or a split, cause one or more parcels to be retired while creating one or more new parcels. A record driven workflow is usually limited in its spatial extent and has a well-defined time frame and methodology.

4.2. <u>Quality Driven Workflows</u>

‘Quality Driven’ workflows on the other hand are designed to improve quality. Quality is defined subjectively and differently between organizations and between parcel types. Configured Topology rules and Attribute Rules help define ‘quality’ and errors can be fixed using a systematic and/or using an ‘Ad-Hoc’ approach. Running Least Squares Adjustment is another example of a quality driven workflow that can help detect blunders, evaluate and improve spatial accuracy.

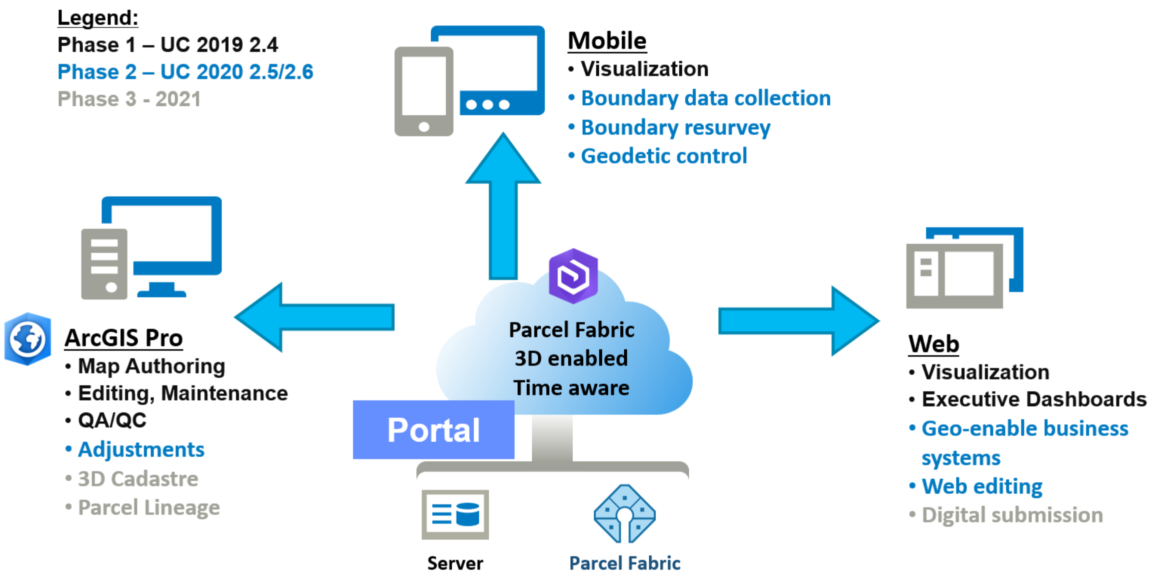
4.3. <u>Tasks for repeatable workflows</u>

Parcel Fabric 2.0 ships with common workflows in the form of ‘Tasks’ in ArcGIS Pro. Tasks are designed to capture best practice and guide new users in a ‘step by step’ fashion. A step can not only provide the user with the correct tool, but also use configurable business language, set up the correct map and layer settings, perform selection actions and many more actions that reduce mouse clicks to make tasks very efficient. The shipped tasks are fully configurable and can be extended and tweaked as needed.

5. PARCEL FABRIC 2.0 VISION AND ROADMAP

Parcel Fabric 2.0 is designed for the next 15-20 years. It continues to evolve and offer additional capabilities with each new release of the software. Parcel Fabric 2.0 is driven by a community of customers and experts.
Future areas of development include:

- Evaluation and improvement of spatial accuracy using least squares adjustment.
- Additional support for 3D Cadastre
- Digital Submission
- Parcel lineage depiction
- Parcel web editing
- Geo-enabling business systems
- Field workflows for coordinate based cadastre
- Machine learning for cadastral use cases



6. CONCLUSIONS

Parcel Fabric 2.0 was designed for the next 15-20 years for a wide variety of cadastral purposes. A cadastral 'purpose' should be free to evolve and grow over time. Parcel fabric 2.0 offers many capabilities, not all of which need to be implemented straight away and can be configured to meet specific business requirements and workflows. Parcel Fabric 2.0 is more than just an information model, but a cadastral solution that exposes many capabilities for a variety of 'purposes' in 2D and 3D. Parcel Fabric 2.0 is a foundation that will keep evolving to meet requirements of future 'purposes'.

REFERENCES

Soffers, P. & Hagemans, E.. (2017). Re-linking survey documents with the cadastral map. GIM International. 31. 29-31.

Janecka, Karel & Karki, Sudarshan & Oosterom, Peter & Zlatanova, Sisi & Kalantari, Mohsen & Ghawana, Tarun. (2018). 3D Cadastres Best Practices, Chapter 4: 3D Spatial DBMS for 3D Cadastres.

Stoter, Jantien & Ploeger, Hendrik & Oosterom, Peter. (2013). 3D cadastre in the Netherlands: Developments and international applicability. Computers, Environment and Urban Systems. 40. 56–67. 10.1016/j.compenvurbsys.2012.08.008.

Lemmen, Christiaan & Oosterom, Peter & Bennett, Rohan. (2015). The Land Administration Domain Model. Land Use Policy. 49. 535-545. 10.1016/j.landusepol.2015.01.014.

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.

CONTACTS

Amir Bar-Maor
Esri
380 New York Street
Redlands, CA 92373
USA
Tel. +1 909 793 2853
Email: abarmaor@esri.com
Web site: www.esri.com