https://doi.org/10.4233/uuid:5af28bb8-ab49-4ec5-bf9e-e1c3639215a8

Mapping ArcGIS Parcel Fabric to LADM - Commonalities, Gaps and Implementation

Amir Bar-Maor, The Netherlands

Key words: LADM, Parcel Fabric, ArcGIS, SOA, Conformance, Implementation.

SUMMARY

Esri's ArcGIS second generation of the parcel fabric was designed with LADM in mind. Unlike LADM which is conceptual, the parcel fabric information model is a physical information model. The parcel fabric is designed to meet the industry needs for the next 15-20 years.

This paper will map the parcel fabric to LADM, use LADM abstract test suite for conformance and identify the gaps with the parcel fabric as well as LADM.

A key driver for the parcel fabric was to make it as easy as possible to implement: easy data migration, extendibility, configuration over customization, built-in configurable quality control, great defaults for layer symbology & labeling, and configurable workflows to reduce the learning curve and promote best practice. The implementation pattern will be examined in the context of LADM.

Another key aspect is a service-oriented architecture and the use of web services to expose the information model, metadata, and capabilities.

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1. THE PARCEL FABRIC INFORMATION MODEL

The parcel fabric provides a comprehensive framework for managing, editing, and sharing parcel data in both a multiuser and single-user environment. In a multiuser environment, the parcel fabric can be edited and maintained using a services-based architecture. A services-based architecture allows you to share the parcel fabric across all platforms (desktop, mobile, and web) and different workflows can be enabled on different clients in the field and in the office.

Figure 1. Services allow you to share the parcel fabric across all platforms (desktop, mobile, and web)

A parcel fabric stores a dataset of connected parcels or parcel network. Parcels are composed of polygon features, line features, and point features. Parcels are added to the parcel fabric as parcel types. A parcel type is composed of a polygon and line feature class and is defined by your organization.

When a parcel fabric is created, a geodatabase topology is also created. The parcel fabric uses a set of predefined geodatabase topology rules and attribute rules to define parcels and model parcel behavior. Geodatabase topology rules define the spatial relationships between parcel features, and attribute rules define behavior that is specific to parcel features.

1.1 The Parcel Fabric Data Model

A parcel fabric stores a dataset of connected parcels or a parcel network. Parcels are composed of polygon features, line features, and point features.

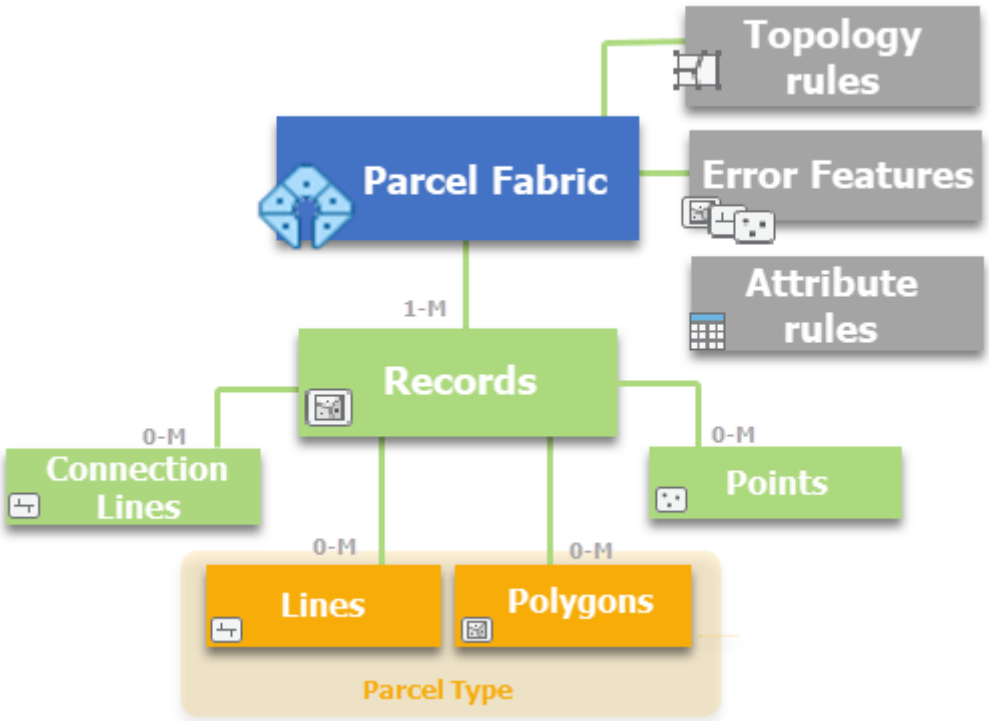

Figure 2. Parcel fabric conceptual information model

1.2 Records

The parcel fabric is a record-driven system. The parcel fabric organizes parcel data based on the form in which it was originally recorded in a record feature class. Parcel data is usually recorded on records such as plans, plats, deeds, and records of survey. The parcel fabric preserves historic and parent parcels. By capturing the legal record that created or retired a parcel, the parcel lineage can be tracked in both directions.

1.3 Parcel Types

Parcels are added to the parcel fabric as parcel types, and each parcel type has its own polygon and line feature class. The line feature class represents parcel boundaries and can store survey measurements (COGO) from the recorded document. The polygon feature class is defined by the parcel lines (metes and bounds) and/or by the points and represents the recorded parcel with a stated area.

You can add as many parcel types as necessary for your organization. For example, your organization may manage both ownership, tax parcels and easement parcels.

The parcel type polygon and line feature classes have a set of predefined system attribute fields and can be extended with user-defined attributes, domains, and related tables.

1.4 Points

Points represent physical, coordinated x,y,z locations on the ground. Points in the parcel fabric are used to model parcel corners, endpoints of connection lines, points along a road centerline, survey control, tie points, and other forms of cadastral reference points.

Points in the parcel fabric have the following characteristics:

- Points represent single locations for connecting the ends of multiple parcel lines.
- Points exist independently of parcels and maintain connectivity and topological integrity between parcels and parcel lines.
- Points can be fixed or nonfixed. Points with fixed shapes do not move in editing processes such as a parcel alignment.

1.5 Connection lines

Connection lines are used to represent dimensions between points that are not parcel boundaries. Connection lines are associated with the legal record that created or retired them.

Connection lines can be used to do the following:

- Connect parcel corner points across rights-of-way (roads).
- Connect parcel corner points to control points.
- Represent road centerlines.

1.6 Topology and attribute rules

The parcel fabric uses geodatabase topology rules and attribute rules to define parcels and model their behavior. Geodatabase topology rules define the spatial relationships between parcel features, and attribute rules can be configured to define behavior that is specific to parcel features. Attribute rules can also be configured to define enforce data quality in the parcel fabric. You can define additional topology rules and attribute rules to enforce data quality standards in your organization.

1.7 Adjustments

Least-squares adjustments can be run on the parcel fabric to evaluate and improve the spatial accuracy of parcel points. When a least-squares adjustment is run, the results of the adjustment are stored in adjustment feature classes for analysis and visualization purposes. If the results in the adjustment feature classes are acceptable, they can be applied to the parcel fabric feature classes.

Adjustment results are stored in the following feature classes:

- AdjustmentLines—Stores and displays adjusted and statistical data for adjusted parcel type and connection lines
- AdjustmentPoints—Stores and displays adjusted and statistical data for parcel fabric points

- AdjustmentVectors—Stores and displays the shifts between parcel fabric points and their adjusted points

2. MIGRATING, EXTENDING AND CONFIGURING THE PARCEL FABRIC

Since most cadastral datasets suffer from data quality issues such as topological errors, the parcel fabric was designed to accommodate data in any condition and provide the organization with the capabilities to evaluate and fix their quality issues. The migration workflow is simple:

1. Create a new parcel fabric
2. Add parcel types
3. Extend the information model
4. Append the source data
5. Create parcel records
6. Build the parcel fabric to create any missing features

The parcel fabric information model can be extended by:

1. Adding additional fields as needed
2. Adding domains (AKA 'code list') to certain fields
3. Add and configure topology rules to model the correct parcel behavior
4. Add and configure attribute rules to model the correct parcel behavior
5. Enable versioning to allow multi-user editing
6. Enable replica tracking, editor tracking and add GlobalIDs (UUID) to allow for disconnected editing capabilities.
7. Add other capabilities such as contingent values, subtypes and metadata.

Extending and configuring the information model does not require any coding and is simple to perform. Once the information model is extended it can be exported to a schema only XML document that can be shared and imported between organizations or environments (development, staging and production). Organizations can continue to extend the information model to meet future business requirements at any future point of time.

A parcel fabric is stored in a geodatabase that can be stored in the following DBMS: MS SQL Server, PostgreSQL, Oracle, SQLite (mobile geodatabase) or a local file geodatabase.

3. SIMILARITIES BETWEEN LADM AND THE PARCEL FABRIC

The 1st generation of the parcel fabric was designed and released prior to the release of LADM and was based on a the 'cadastral XML' format which is a similar the LandXML format. The 1st generation of parcel fabric was similar to LADM but did not pass all the LADM conformity tests. The 2nd generation of the parcel fabric, released in 2019, was designed to conform with LADM. Cadastral organizations typically manage 'Parties' and the 'RRR' in their a land registration system which is integrated to the GIS system. The parcel fabric, by design, does not cover those packages.

Similarities:

- Both LADM and the PF models are flexible and extendable to meet unique business needs (‘profiles’).
- Both models are object oriented.
- Relationships – both models use relationships between entities.
- Both account for the physical representation and the legal representation.
- Both support multiple systems of legal descriptions, formal and informal.

The similarities can be simply explained: both the conceptual LADM and the physical parcel fabric information models are driven by the same business requirements to describe the same entities. Both use abstract terminology

4. MAPPING LADM TO THE PARCEL FABRIC

LADM and parcel fabric use different ontology that can be easily mapped. The term ‘parcel’ in the parcel fabric is used very loosely and can describe a right, restriction, or a responsibility. Organizations are using a ‘parcel’ to model administrative boundaries or land tenure, land or water bodies, legal boundaries and natural boundaries, 2D and 3D, formal rights or customary rights, as well as cadastral frameworks like the US PLSS (Public Land Survey System).

This describes the high level mapping between LADM and the parcel fabric classes.

4.1 LADM Spatial Unit

In LADM a Spatial Unit (SU) is single area (or multiple areas) of land and/or water, or a single volume (or multiple volumes) of space. The parcel fabric spatial units are called ‘parcels’. A parcel fabric can have as many parcel types as needed. When parcel types are created the system designer can provide a meaningful name and alias. Examples: conveyance division, encumbrance, tax. LADM SU have 2 specializations: building units (legal space) and utility Networks (legal space for a utility). Organizations use the parcel fabric parcels to manage the legal spaces for condo units as well as utility easements.

4.2 LADM Basic Administrative Unit

LADM ‘Basic Administrative Unit’ - administrative entity, subject to registration, or customary right, or another social tenure relationship, consisting of zero or more spatial units against which unique and homogeneous rights, responsibilities or restrictions are associated to the whole entity, as included in a land. When a parcel type is created in the parcel fabric it can be designated as administrative. System designers can add as many administrative parcel types as needed.

4.3 Boundary

LADM ‘Boundary’ is defined as a set that represents the limit of an entity. In the parcel fabric each parcel type consist of a polygon feature class and a boundary lines feature class.

Boundaries can represent straight lines, true curves, spiral curves and natural boundaries (line string). Boundary lines extremities have a point.

4.4 LADM Source

In LADM a source is defined as a document providing legal and/or administrative facts on which the land administration (LA) object, restriction, responsibility, basic administrative unit, party, or spatial unit is based. Any kind of document may be added as a source. The parcel fabric records feature class are the equivalent. Any feature created in the parcel fabric: a parcel, boundary line, connection line or point are associated to a record. Records are the basis for parcel lineage and historic parcels. The record feature class is the footprint of the legal transaction and is often tied to the document management system.

4.5 LADM Version Object

In LADM a LADM a VersionedObject is used to manage and maintain historical data in the database. History requires, that inserted and superseded data, are given a time-stamp. In this way, the contents of the database can be reconstructed, as they were at any historical moment. Similarly, the parcel fabric uses versioning which also allows for multiuser editing and isolation between versions. 'Branch Versioning' is temporal and allows users to connect and view historical moments in time using services from any client (desktop, web and mobile).

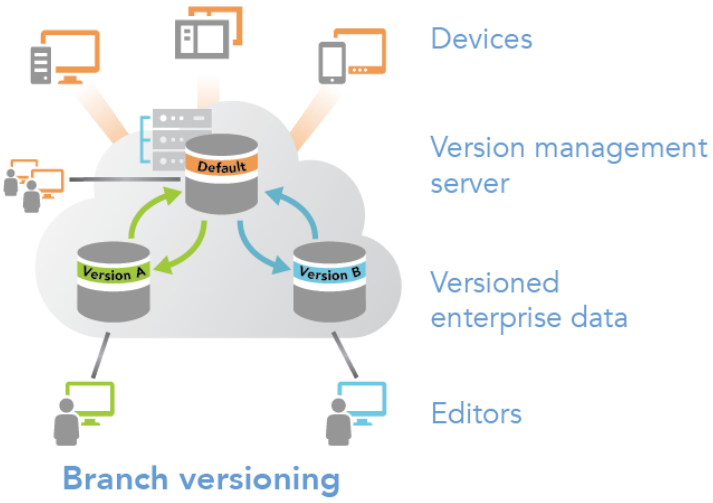

Figure 3. Branch Versioning – service based and temporal

4.6 LADM Code List

LADM code list are called domains is ArcGIS. Domains restrict the potential values for a field and prevent user data entry errors. A domain can have a coded list of potential values (not only strings) or a range of numerical values. A domain can be applied to different data types: short and long integers, double, string etc. The parcel fabric comes with a minimal set of domains and allows organizations to add their own.

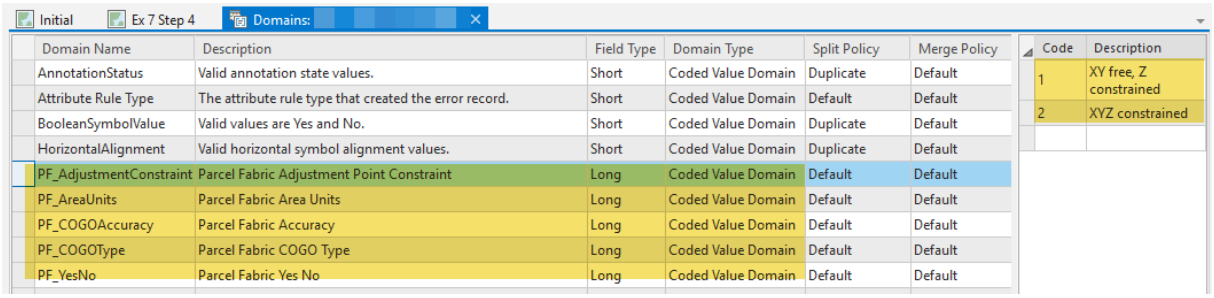

Figure 4. LADM code list are implemented using geodatabase domains

4.7 LADM Surveying and Representation Subpackage

LADM 4 classes of Surveying and representation: Point, LA_SpatialSource, LA_BoundaryFaceString, and LA_BoundaryFace. Parcel fabric matching classes are: Parcel fabric points feature class, Record feature class, Boundary lines feature class and future faces modeled as part of the new '3D Object' geometry type. The Records feature class has a 'record type' field that can be used to differentiate between sources. Some organizations capture the sources' status to track parcels that are in 'design'/'preliminary' state and later switch the record to a 'registered' / 'recorded' state.

5. THE PARCEL FABRIC COVERS A SUBSET OF LADM

The Parcel Fabric is a subset of LADM. Parcel Fabrics do not over the LA_Party and the LA_RRR as those are usually managed in dedicated business systems such as a land registration system or a CAMA system.

If needed, the geodatabase can be extended with additional tables and relationships to model the LA_RRR and the LA_Party. This is usually done for first registration projects (FFP) that don't have a mature land registration system yet. Integration is another driver for the Parcel Fabric SOA (Service Oriented Architecture)

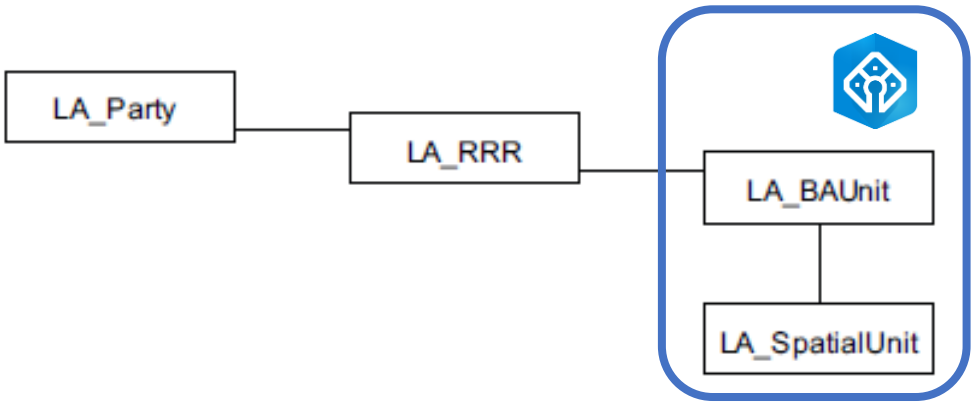

Figure 5. Parcel fabric covers a subset of the LADM packages

6. LADM PROFILES

LADM is a generic domain model that is expandable. Organizations can add additional classes, relationships and attributes to meet their specific business requirements. Extending LADM to a specific region is referred as a 'country profile'. The parcel fabric has been extended to well known information models such as LGIM (Local Government Information Model) in the united states which complies with the national FGDC Cadastral Data Content Standard for NSDI, the CPDM (Canadian Parcel Domain Model), and many others. The flexibility of the parcel fabric allows organizations to add their own attributes, domains, quality rules to support their specific business requirements and workflows.

7. ABSTRACT TEST SUITE

LADM Annex A provides an abstract test suite to test whether an application is conformant with LADM in terms of package and level. Using the test suite the parcel fabric has been tested for the LA_BAUnit and LA_SpatialUnit for levels 1, 2, and 3 and has been found conformant. Using ArcGIS Pro the parcel fabric it is easy to modify the parcel fabric feature classes and use LADM ontology. Code lists have been implemented using domains.

If needed, organizations can also extend the information model to support the LA_Party and LA_RRR packages in their geodatabase. However, it is more common for those to be implemented as part of the land registration system and document management system and integrated to the GIS system.

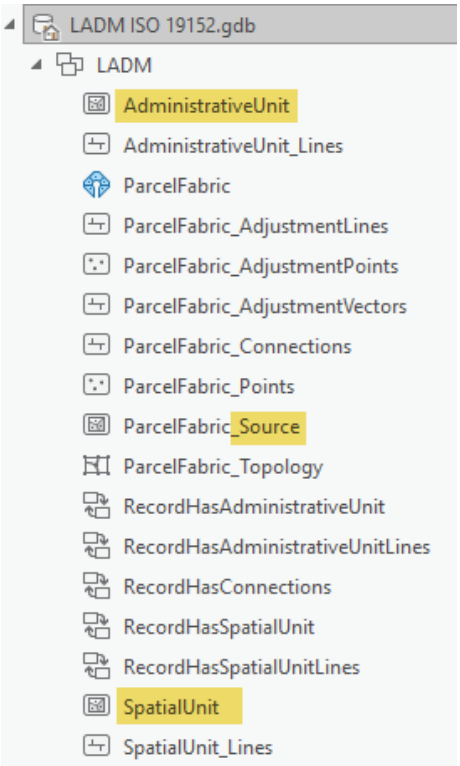

Figure 6. Parcel fabric classes can use LADM ontology

8. DIFFERENCES BETWEEN LADM AND THE PARCEL FABRIC

Here are key differences between LADM and the parcel fabric:

- LADM is abstract and conceptual where the Parcel Fabric can be seen a physical implementation of LADM
- LADM is designed to be used as a reference where the parcel fabric is a 'ready-to use' extendable implementation of LADM
- Parcel fabric controls lines that do not form boundary lines called connection lines. Connection lines are usually used as survey tie lines, road centerlines or reference lines. Connection lines densify the survey network and contribute to the Least Squares Adjustment (LSA).
- Quality – the parcel fabric schema comes with 'built-in' quality rules that govern the parcel behavior. Quality rules are defined using topology and Attribute Rules. Topology rules define the allowed topological relationships between classes where Attribute Rules use a simple script language that can validate attributes and geometry.
- The parcel fabric tracks parcel lineage (parent-child). When a parent parent parcel becomes historic it also retire the appropriate boundary lines and points.
- LADM uses OID (Object ID) as a UUID (Universal Unique Identifier). The parcel fabric uses both the RDBMS OIDs as well as a GlobalID to gurentee uniqueness within a geodatabase and between geodatabases. GlobalIDs allow for data to be taken offline and exchanged between organizations while maintaining uniqueness.
- Metadata – each of the parcel fabric feature classes have their own metadata. Most classes also have feature level metadata using attributes to manage units, spatial accuracy and editor tracking.
- Security – parcels are part of the 'system of record' and should only be modified by accountable editors. All parcel fabric classes have editor tracking and can only be edited by a named user that is authenticated and has been granted permission to edit. Editors can be constrain to only edit child version and have to pass quality assurance (QA) by a person authorized to push the edits to the master view (default version). All edits, including deletes, are archived when using branch versioning.
- Workflows – the parcel fabric come with predefined workflows that can be modified and extended using the Tasks frameworks.
- The parcel fabric is an implementation of LADM and uses web services. Web services improve collaboration and provide current data to all client types (desktop, web and mobile). Web services and Service Oriented Architecture (SOA) have many advantages – they improve collaboration, integration between systems and provide a central location to manage user privileges. Using web services opens authoritative data to all stakeholders that can consume it in a variety of formats including JSON, OGC WFS and others.

9. CONCLUSIONS

The 1st generation of parcel fabrics, which was already released before LADM ISO 19152, was partially conformant with LADM because both information models catered to the same industry and both were designed the same business requirements. The design process of the 2nd generation of parcel fabrics in 2015 could already leverage and use LADM as reference. The 2nd generation of parcel fabrics is conformant with LADM and allows organizations to extend it to meet their unique business requirements. The parcel fabric was also designed to meet to solve many implementation challenges that are outside of the current scope of LADM. Easy data migration process, built-in quality control and predefined workflows make the parcel fabric easy to deploy and adopt. Service Oriented Architecture and web services makes it easier to integrate between the parcel fabric to business system were the LA_Party and LA_RRR packages are typically managed (e.g. land registration system).

Other implementation details include security, permission management and accountability that are important in a system in record. Parcel lineage and archiving allows you to view historic parcels or view the data as it was in any other historic moment in time. As LADM continues to evolve and improve so does the parcel fabric and the entire ArcGIS ecosystem.

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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.

CONTACTS

Amir Bar-Maor
Esri
380 New York Street
Redlands, CA 92373
USA
Phone: + 1 909 793 2853
E-mail: abarmaor@esri.com
Website: www.esri.com