Technological Trends Driving the Modernization of Cadastral Systems

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SUMMARY

The modernization of cadastral systems is increasingly shaped by demand-driven business requirements and rapidly evolving technological trends. Key business needs include system accessibility across various platforms, robust data quality management adhering to organizational business rules, 3D data representation, and high levels of performance and scalability. Emerging technologies, particularly advancements in artificial intelligence (AI), are accelerating the demand for highly efficient and adaptable cadastral systems.

Moreover, there is a growing emphasis on leveraging configurable, out-of-the-box software solutions to simplify system implementation and maintenance. Modern cadastral platforms must evolve in step with technological advancements while minimizing reliance on specialized developers and complex, customized upgrades.

This paper examines the Parcel Fabric in ArcGIS as a case study of a platform that effectively addresses these demands, illustrating how it meets the diverse needs of various cadastral systems while aligning with contemporary technological trends.

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Esri's parcel fabric: A Modern Cadastral Solution for the Future

Esri's fourth-generation parcel fabric solution represents a significant advancement in cadastral technology, designed to meet evolving business and operational requirements. Built within ArcGIS Pro, this modernized solution offers seamless integration across desktop, web, and mobile platforms, whether deployed on-premises or in the cloud. Engineered to support cadastral workflows for the next 15–20 years, the parcel fabric introduces key innovations that enhance data accessibility, multi-user collaboration, 3D and 4D visualization, and system scalability.

The parcel fabric is an LADM-compliant data model and has technologically evolved to meet the following modern business requirements:

- Cloud-based deployments and offline editing
- Multiuser, concurrent editing
- Data migration from diverse sources
- Data quality management that includes least-squares adjustment
- Focused tools and workflows for parcel editing

Designed for both experienced professionals and new users, it streamlines operations, enhances productivity, and supports the digital transformation of land administration.

As the global leader in Geographic Information System (GIS) technology, Esri remains committed to advancing geospatial solutions. With a privately held and debt-free structure, the company reinvests up to 30% of its annual revenue into research and development, driving continuous innovation in the cadastral domain.

Technology Drives Business Requirements and Expectations

Technology has transformed modern expectations, including:

- Web services. Stakeholders expect to be able to access and edit their data from any device.
- Trustworthiness. Data should be current and accurate for it to be trusted for decision-making processes.
- Security. While data should be viewable by the public, only a subset of named users should be able to modify it.

- Performance, scalability, and efficiency. Automated quality assurance and efficient cadastral data ingestion can significantly reduce processing time. Optical Character Recognition (OCR) technology can assist in extracting dimensions from deeds, greatly reducing hours spent on tedious data entry.
- Artificial intelligence and machine learning. Assistants and agents can perform operations in software, which can reduce the learning curve for new and inexperienced users. Large language models such as ChatGPT can assist in processing plans and deeds for digital submissions.

Web Services and Services-Oriented Architecture

With a service-oriented approach, cadastral data can be accessed and modified seamlessly across desktop, web, and mobile platforms. The enterprise deployment of the parcel fabric leverages web services and RESTful APIs (JSON), enabling efficient data management and integration. By adopting a Service-Oriented Architecture (SOA), the need for traditional ETL (Extract, Transform, Load) processes is minimized. Instead of duplicating data for various stakeholders, administrators can control data publication and access privileges—ensuring, for example, that public users have read-only access.

The use of modern, lightweight, and compressed formats such as JSON and Google's Protocol Buffers enhances performance by reducing data transfer and parsing times. The stateless nature of the REST API ensures that no client session data is stored on the server, optimizing communication by minimizing overhead. Further performance enhancements, such as client-side caching of maps and layers, improve efficiency.

Another key advantage of SOA is the ability to offload computationally intensive tasks to the server. By executing memory- and CPU-heavy processes on the server rather than on mobile devices or web browsers, the system leverages server resources more effectively while maintaining proximity to the core data, ensuring faster processing and improved overall system performance.

Multi-user Concurrent Editing

In an enterprise deployment, the parcel fabric uses multi-user branch versioning. With versioning, multiple users can edit simultaneously in an isolated fashion without creating copies of the data. Once edits are complete on a version, it can undergo quality assurance (QA) before the updates are reconciled with the main, default version.

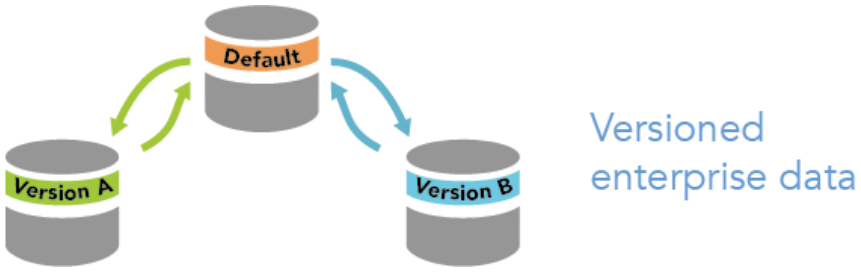

Figure 1. Multi-user editing is supported by versioning

In ArcGIS Pro, branch versioning has enhanced editor-tracking where every edit is tracked by date and time. Users can view historical states of the data at any moment in time.

A few advantages of the versioning approach include:

- Performance and scalability of enterprise geodatabases
- Security. In an enterprise deployment, user privileges and access are managed using groups and user-roles. Each operation is tracked with the user's identity. Named users must authenticate to login to the system.
- Ability to move to previous moments in time, which enables 4-dimensional (4D) Cadastre capability.

Offline Editing

Many organizations require the ability to edit data in offline workflows. Offline workflows might be necessary when internet connections are not reliable, or work needs to be performed in the field.
The parcel fabric supports offline editing where users can extract parcels to a local mobile geodatabase (SQLite). Once edits are complete, data is synchronized back to the editing version of the enterprise geodatabase.

Data Migration and Configurability

The parcel fabric in ArcGIS Pro is LADM-compliant and supports seamless data migration from diverse sources. Parcel polygon features can be appended from both simple feature classes and shapefiles. Additional migration workflows accommodate digital submissions in CAD format, where parcels can be built directly from CAD lines.

Designed for flexibility, the parcel fabric data model can adapt to any cadastral system and is easily configured to meet organizational requirements. Organizations can extend the model by adding custom parcel types, attributes, and domain values (code lists) while also defining their own data quality rules to ensure compliance with internal standards.

Parcel data can be migrated into the parcel fabric in its existing state and does not need to be cleaned or processed. After migration data quality issues can be identified and addressed using a comprehensive suite of built-in validation and data quality tools.

Focused Tools and Workflows for Parcel Editing

Parcel editing workflows usually involve the creation of new parcels in response to land transactions. Land transactions are typically recorded on legal source documents, which represents the record for the parcel. In the parcel fabric, parcel creation workflows are known as 'record-driven' workflows where the parcel record triggers the creation of new parcels. In the parcel fabric, a record feature is created first before creating new parcels. The record feature is set as 'active' in the editing map and all newly created parcel features will be associated with the record feature in the geodatabase.

Parcel editing workflows are performed with focused parcel editing tools such as parcel traverse, parcel merge/combine, parcel split and divide. When these tools are used in record-driven workflows, parcel lineage is established where the active parcel record retires the original parent parcels as historic.

Parcel lineage relationships can be visualized using link charts in ArcGIS Pro and explored as part of chain-of-title research in the parcel fabric.

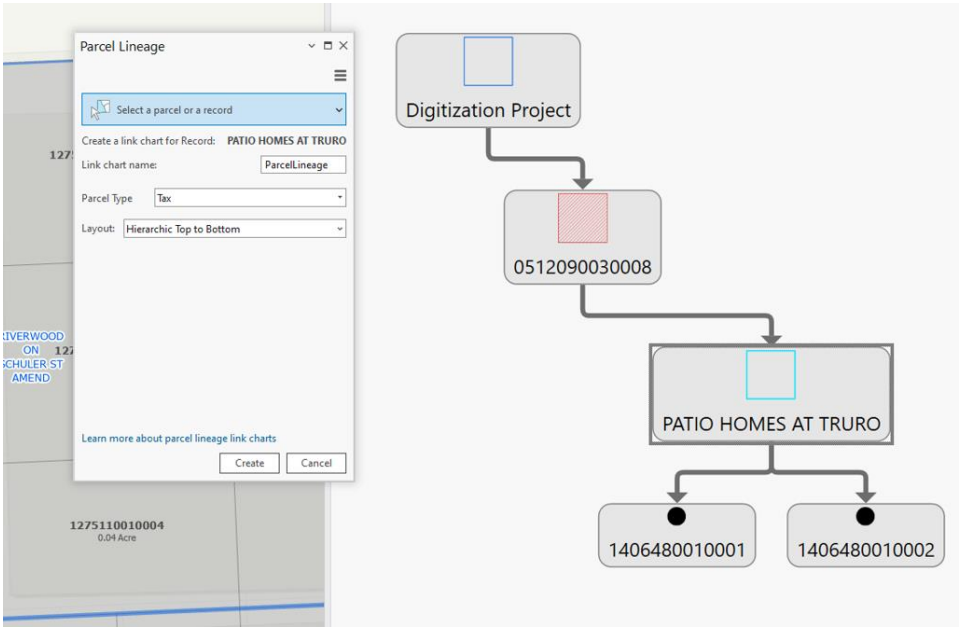

Figure 2. Parcel lineage in the parcel fabric

3D Cadastre

The parcel fabric supports the requirements of a 3D cadastre with z-enabled parcel points and the storage of strata parcels. Strata parcels represent floor levels both above and below the ground, for example, condominiums, flats, apartments, and basements.
Tools are available for improved data entry of floor plans and users can use map exploration tools to display floors in three dimensions (3D). The parcel fabric uses an attribute-driven approach (2.5D), which has the advantage of always displaying data relative to the most recent elevation surface model.

Tools and Scripting for Data Quality Management

Data quality is important in any system of record. Cadastral data is used as a foundation layer for many other datasets and processes. For cadastral data to be trusted as a source, it must be of high quality and communicate where data issues might exist. ArcGIS Pro includes tools and functionality that can be configured specifically for your business rules to detect data quality issues in the parcel fabric.

Scripting and attribute rules

Organizations often rely on scripting and expressions to define data quality rules for cadastral data. While desktop environments support languages like Python, these are impractical for mobile and web applications due to their large suite size and security risks.

In ArcGIS Pro, Arcade is a lightweight and secure expression language that can run across all platforms. Arcade is a GIS-centric expression language that provides spatial functions as well as access to a feature's geometry.

In ArcGIS Pro, attribute rules leverage Arcade to enforce business logic and data quality standards. Attribute rules can be configured to automate attribute population, restrict invalid edits, and perform real-time quality assurance. The parcel fabric includes preconfigured attribute rules that can be enabled and configured for your organization. Additionally, organizations can also configure their own attribute rules to ensure data integrity.

Topological tools

ArcGIS Pro uses geodatabase topology to enforce topological relationships between parcel features. Topology rules are used to define the allowed topological relationships in the parcel fabric. Additionally, organizations can add their own rules to define topological relationships between parcel features and other features. Topology validation can be performed using web services from any client.

The parcel fabric also includes a set of dedicated tools to detect common topological alignment issues. These include gap and overlap detection, focused parcel alignment tools and parcel curve correction tools.
With focused data quality tools, the parcel fabric works out-of-the box and minimizes the need for custom tools.

Least-squares adjustment

Increasingly, there is a need for spatial accuracy in cadastral data. The least-squares adjustment engine in the parcel fabric performs both free network and constrained, weighted adjustments on the parcel data.
Free network adjustments check measurement consistency and identify outliers. Constrained, weighted adjustments evaluate and improve the spatial accuracy of parcel corners. The parcel fabric uses the robust DynAdjust least-squares adjustment engine and uses GIS layers for analysing and displaying adjustment results.

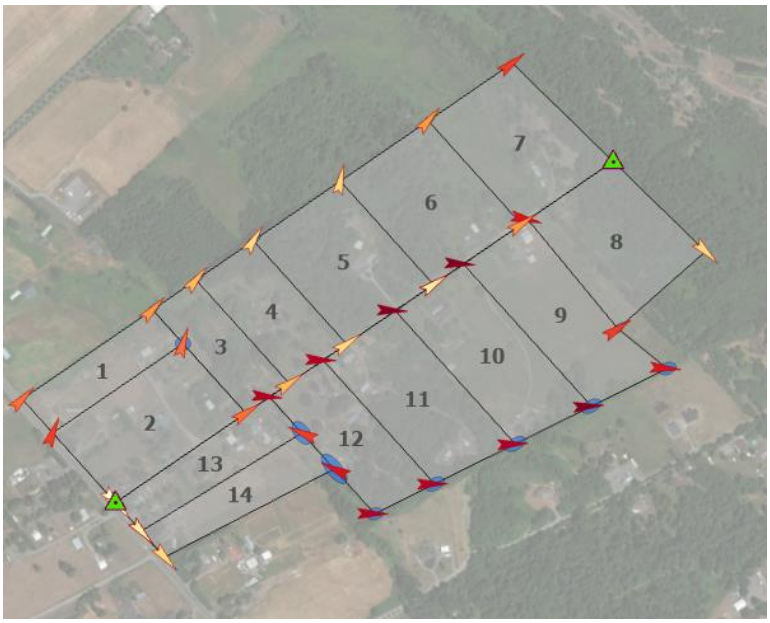

Figure 3. Least-squares adjustment vectors

Performance, Scalability and Efficiency

Cadastral systems need to be able to scale from a few hundred parcels to a few million parcels while providing the same user experience and performance. In ArcGIS Pro, such scalability is achieved by using proven scalable DBMS products such as Oracle, MS SQL Server, and PostgreSQL. ArcGIS Enterprise can also be scaled up by adding additional resources such as additional servers for load balancing and high availability technology.

Editing and data entry of cadastral data can be tedious and inefficient. With advances in modern technology, tedious software processes can be greatly improved and, in some cases, eliminated.
Automated data quality processes can reduce the amount of corrective editing on parcel data and the use of attribute rules can eliminate data entry errors.
In the parcel fabric, parcel dimensions are entered using a traverse tool that is designed for single handed entry using the numeric keypad. An extensive list of documented keyboard shortcuts is available for rapid and efficient data entry of dimensions.

Artificial Intelligence and Machine Learning

With the emergence of Large Language Models and Artificial Intelligence (AI), software processes such as data migration, data entry and data cleanup can be performed by AI agents and operators.
Esri is actively working on AI assistants in ArcGIS Pro to perform common operations and reduce the learning curve for new and inexperienced users.

OCR (Optical Character Recognition) technology can assist in extracting dimensions from deeds, reducing time spent on tedious data entry.
Typically, parcel editors enter parcels from deeds that start at a commencement point, go to a 'point-of-beginning' (POB) and then form a closed loop. With OCR technology, scanned documents can be automatically processed in the parcel fabric. In this scenario, a parcel traverse can be automatically created from a scanned deed instead of the manual data entry of dimensions. This will greatly improve the rate at which new parcel data can be added to the parcel fabric.

Conclusion

Technology has transformed and driven the business requirements of modern cadastral systems. The parcel fabric in ArcGIS Pro has responded to these requirements by providing a robust, scalable platform for multi-user editing on desktop, web, and mobile clients. Furthermore, the parcel fabric provides a configurable platform that minimizes the need for customization.
The architects of land information systems require the ability to build technological solutions that are easily configured without the need to create customized tools, and yet flexible enough to accommodate the business needs of their clients. The parcel fabric in ArcGIS Pro is a pre-configured solution that evolves with current technological trends and is easily adapted to the varying business needs of different land record systems.

The parcel fabric provides a flexible data model and focused parcel-aware editing tools that can be used in efficient, record-driven workflows. These two functionalities minimize the

need for customization. For data quality management, configurable frameworks in the form of attribute rules, geodatabase topology can meet the needs of any cadastral organization.

As technology and business requirements continue to evolve, Esri continues to work closely with experts and customers to develop new and innovative capabilities that improve efficiency and quality of cadastral records.

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