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Executive summary

Configurable GIS solutions crafted with ArcGIS technology support mapping and managing land at different points along the land rights continuum. As technology advances, parcel mapping and management becomes more intuitive and automation of quality control checks and parcel edits more accessible. The Land Administration Domain Model (LADM) may also be configured to compliment GIS solutions. The result is scalable land administration that can answer to challenges in several different contexts, including the Arab context. Common challenges identified include but are not limited to technological development rates, National Government policy and interest in land administration and adoption of a standard on local, regional and national levels. Examples of implementation that address these challenges along the land rights continuum that may be applied to the Arab context include work done in Colombia and in British Colombia, Canada. A combination of ArcGIS applications configured to meet specific needs along with a core LADM implementation for initial data collection followed by application of a country profile can enable efficient merging of several datasets into a cadastre.

Introduction / background of the content

This paper will discuss challenges in mapping and managing land and how advancements in GIS technology paired with the LADM standard facilitates combination of data from field to municipal or regional land administration to cadastre. Collected parcel data that has been web enabled supports integration with external systems such as land registry systems. The second section of this paper will discuss different use cases that show this capability. The third section will present a scenario that illustrates how a combination of ArcGIS applications and LADM may be applied to field data collection, municipal parcel management and finally culmination into a national cadastre that may be shared with internal and external stakeholders

LADM and Configurable GIS Technology

As in every region of the world, certain challenges face the Arab context in relation to securing tenure and creating and maintaining a formalized cadastre. Challenges faced in land administration are often defined by several factors advancing at different rates but can be put into three general categories: technological capability, need or desire of the interested entity and adoption of standards. The first factor encompasses achieving rates of technological development that enable National Governments to create and maintain a cadastre efficiently and integrate with registry workflows. The second lies with the cadastre itself: is securing tenure and recording property boundaries a priority for a country? What stage of formalization are the property boundaries collected and how does that differ across the country? Finally, adoption of a standard such as the Land Administration Domain Model (LADM) that all cadastral data can be collected or maintained by completes the cadastral picture by enabling technology and national needs to meet efficiently.

Technology is advancing at a rate that enables the seamless incorporation of data collected in the field, by CAD or with coordinate cadastre into a parcel management system. Advancements continue to support automated workflows. For example, a land registry system integration may signal a parcel change and that change will be automatically performed by the parcel management system. At a high level, this communication between systems is made possible by bringing parcel data to the web. Application programming interfaces (APIs) work to connect systems together.

At the base of a geographic information system lies the data. Those who use the system must first quantify the data that they have, if any, and decide how to organize it. Then they must begin filling in any gaps in the data, and check for quality control. Adopting a standard such as the LADM facilitates processes from quantification to quality control. An implementation of LADM that can be used for data collection and scaled up to will be introduced in the third section of this paper. First, let's explore the current and future state of ArcGIS to understand how LADM may support collecting and mantinaing property boundaries within GIS.

ArcGIS continues to progress, mirroring current trends in technology. Patterns within every aspect of managing and maintaining a cadastre are rapidly advancing, from field data collection to desktop to automation of processes and expansion into an enterprise architecture. This is not to say that the workflows are becoming more complex. In fact, it is the opposite. As technology advances, the end user of that technology should have a more intuitive experience with fewer components to understand and more reliability. ArcGIS Field Maps is an excellent example. Here, three classic ArcGIS mobile applications that enabled field data collection (Collector), asset tracking (Tracker), field markup (Explorer) have been condensed into one. Field Maps also supports collecting data to several related tables that can be prepared for use in an online smart form, which is important when collecting data with the land administration domain model

Data collected with Field Maps or provided in CAD, coordinate cadastre or shapefile formats may be brought into the ArcGIS Parcel Fabric using ArcGIS Pro or desktop software. The Parcel Fabric continues to evolve and is capable in its current format of supporting the LADM data standard. The parcel fabric data model supports the LADM's Spatial Source as Records and Spatial Unit as polygon Parcel Types.

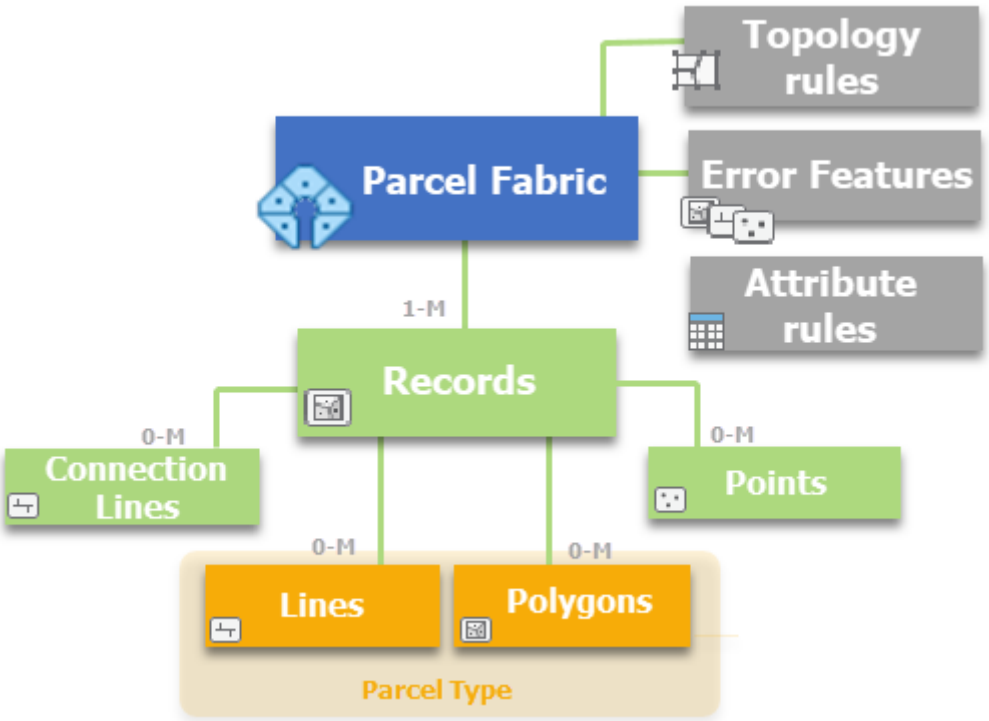

Figure 1. The ArcGIS Parcel Fabric Data Model.

Quality driven workflows validate a parcel fabric and use topological rules to detect common errors. These rules may be customized to include detecting gaps and overlaps in data. Record driven workflows reflect a change in the parcel – whether it is split, merged, etc. The parcel fabric supports single and multiuser editing. In a multiuser environment, the parcel fabric is published to ArcGIS Enterprise, where versioned editing is enabled. ArcGIS Enterprise can be deployed on premises behind a firewall leveraging a local network, or on the cloud. In either case, publishing a parcel fabric to Enterprise also enables access to a powerful REST API which is used to integrate with land registry systems and automate some parcel editing processes.

In the next two sections, case studies leveraging different aspects of the technology detailed above will be discussed and a scenario using both LADM and ArcGIS will be proposed.

ArcGIS and LADM on the Land Rights Continuum

Geographic information systems technology is used at every step in the process of mapping and maintaining land. Over time, ArcGIS has evolved to be a set of components that can be pieced together to solve a problem – from collecting tenure information to managing a national cadastre. Components that see common use in the land administration space include field data collection applications, dashboards, web mapping applications that allow for heads up digitization, desktop software running the parcel fabric, and an enterprise deployment pattern that web enables the resulting parcels – allowing for many more capabilities including integration with land registry systems. Any

configuration of components from this list can be configured to support recording land mapping and management at different points along the continuum. Several configurations may then later be connected to form a cadastre.

Around the globe land is mapped and managed at several points along the land rights continuum, often within the same country at the same time. One country may have national government entities recording land for the first time for entry into a national database, while at the same time some municipalities may be managing their own property boundaries while still others may be managed by the national government in beginning the process of QAQC. ArcGIS components may be aligned to meet each need listed, ultimately culminating in one seamless system for tenure and parcel boundaries, easily linked through web enabled services to a land registry.

When beginning to build a land management system, there are a few common ways to capture property boundaries and enter them into a database within a GIS. If surveyors have visited the property, they may have coordinates denoting the corners or other places along a boundary (coordinate cadastre), they may provide a CAD file or shape file, or comply with digital submission guidelines that have been enacted through policy. (Tim Fella, 2020) All of these cases are supported in ArcGIS by leveraging geoprocessing tools within desktop software. These tools may be added to python scripts to automate ingesting data. Once this data is brought into the geographic information system, it moves to the QAQC process, checking for any overlaps and gaps, or other topological errors.

If property boundaries have not been collected by a surveyor or other entity and provided to the managing office, they may be collected in a fit-for-purpose fashion. In Colombia, the decision to record good enough rather than perfect parcel data is saving over 100 years of labor. (Brent Jones, 2020) Field crews of para-surveyors are trained in using ArcGIS Field Maps on mobile devices to collect parcel boundaries and tenure information using the Land Administration Domain Model (LADM). ArcGIS Field maps enables para surveyors to connect their phones to high accuracy GNSS receivers via Bluetooth to collect data in real time. Boundaries are collected by vertex or point, later represented to the landowner as a polygon for ease of communication. The data is then brought into a database and fed to a web mapping application which provides an interface for community review. After the community has agreed on the property boundaries, this information is sent higher up in the national government for review, and titles later issued. (Ibid.) Since this data will have already been checked for quality, it can be incorporated directly into a parcel management system such as the ArcGIS Parcel Fabric, to be managed either by a local, regional or national cadastre.

If parcels have been collected or are being managed by several local or regional authorities, or both, national cadastres may be interested in bringing all parcels together into one system. At the beginning, middle and end of this process, adopting a standard such as LADM acts as a common language with which to collect new data, manage

existing data and bring the two together seamlessly. Working backwards, one may envision a fully functional ArcGIS Parcel Fabric. It has several parcel types – some are administrative boundaries, other signify property boundaries or even multistory buildings and the units within them. The ownership of each parcel is known because the boundaries have been integrated with a registry system. Now new data from a municipality that has been managing their own data must be brought in. It may be in a different format or schema, making it difficult to add the new data to the existing data. Employing a standard such as the LADM would help to make the process seamless.

The Land Title and Survey Authority (LTSA) of British Colombia had a similar goal to bring all of their parcel data together. A partnership formed between Esri and MDA used industry standard models (at that time the Local Government Information Model or LGIM) to bring several disparate datasets together into one. To accomplish this, the team used desktop software and the ArcGIS Parcel Fabric. In addition, the parcels were made “survey aware” meaning all field survey dimensions were preserved. Later this information was made publicly available using a web mapping application. The result was expected to, “support fundamental economic growth through the province.” (Esri, 2017)

As an international ISO Standard, the Land Administration Domain Model is flexible enough to support land administration along the entire land rights continuum. The model in its own right is flexible enough to support field operations, parcel management and constant changes and additions to property boundaries. When paired with the appropriate components of ArcGIS, it becomes a powerful common language that enables efficiency.

ArcGIS and LADM in Action to Support Scalable Land Administration

This section will explore a scenario where a housing development is being built in an undeveloped area, where parcels will be collected to be managed by the municipal government and will later be integrated into a national cadastre. In moving from one need to another, different components of ArcGIS will be used, as will different aspects of the Land Administration Domain Model.

In this first scenario, a housing authority has planned the layout of the community that will be built but has not yet hired surveyors to take official measurements of the boundaries, although they plan to do so. Ultimately, the property boundaries collected will be maintained by the local municipal cadastre, who is exploring using the Land Administration Domain Model as an industry standard data model. It can be reasonably assumed that the surveyors will report their recordings as either CAD files, coordinate cadastre or shapefiles. The housing authority still wants to capture ownership information on the different parcels as wells as building units being rented, sold or used for commercial purposes.

This first scenario, along with the Fit for Purpose field data collection model, has made the creation of an easily applied core LADM implementation necessary. At its center, the

LADM serves the primary purpose of providing a basis of understanding property boundaries, and the Rights, Restrictions and Responsibilities of the people who own them. (Lemmen, 2012) When pared down to the essentials, a core implementation of the LADM may simply be a Spatial Unit polygon showing the property boundary, related to tables that capture Address, Party, RRRs and corresponding attachments of photographs showing identification or rights to the land.

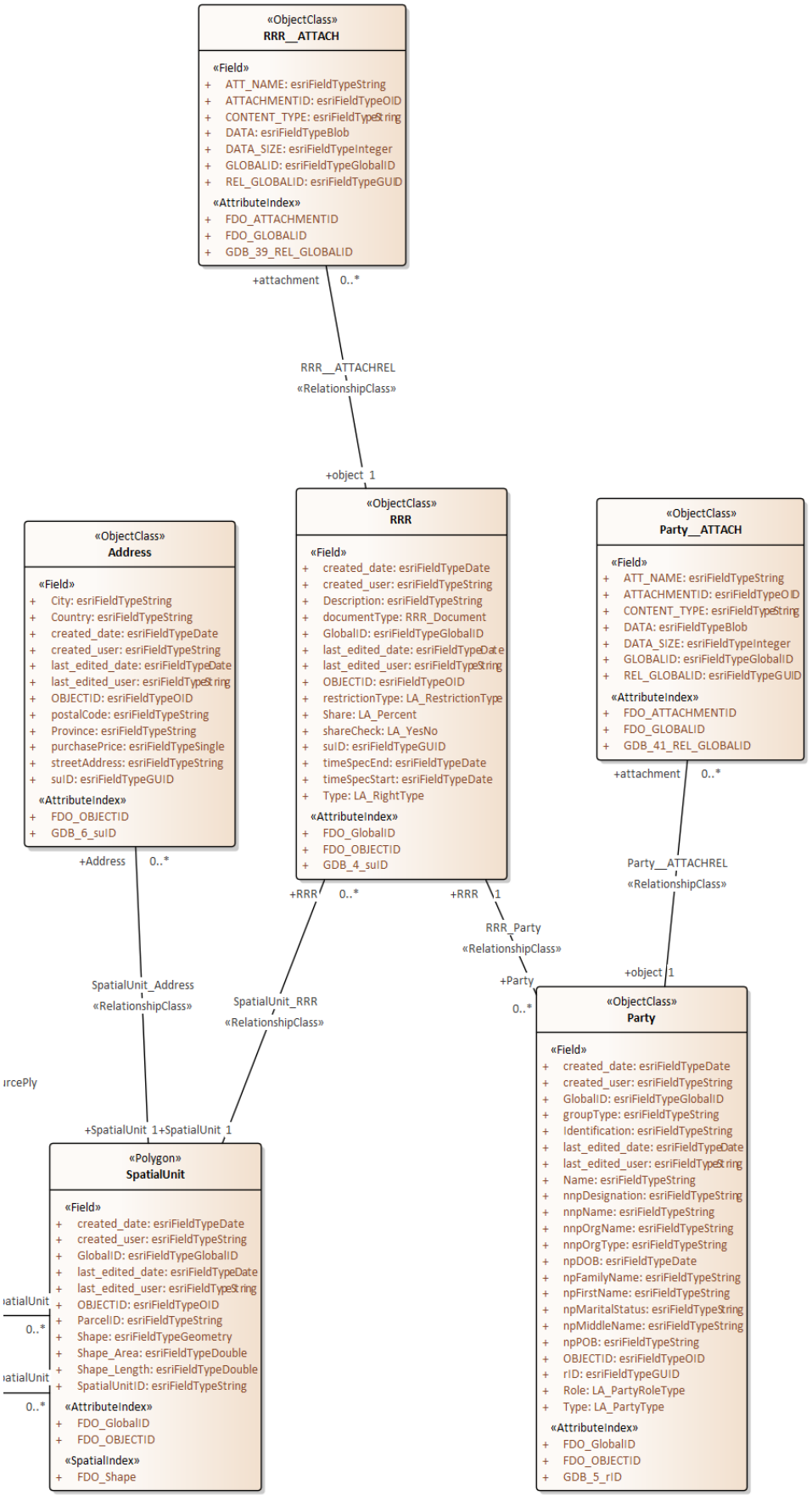

Figure 1. Spatial Unit UML Diagram

A core LADM implementation would also include a Spatial Source polygon. To support field data collection workflows, an optional Spatial Source point has been added if, for example, a legal control or intersection between boundaries needed to be recorded. Each has a related table containing information about the Responsible Party and attachments and is joined to the spatial unit in a many to many relationship.

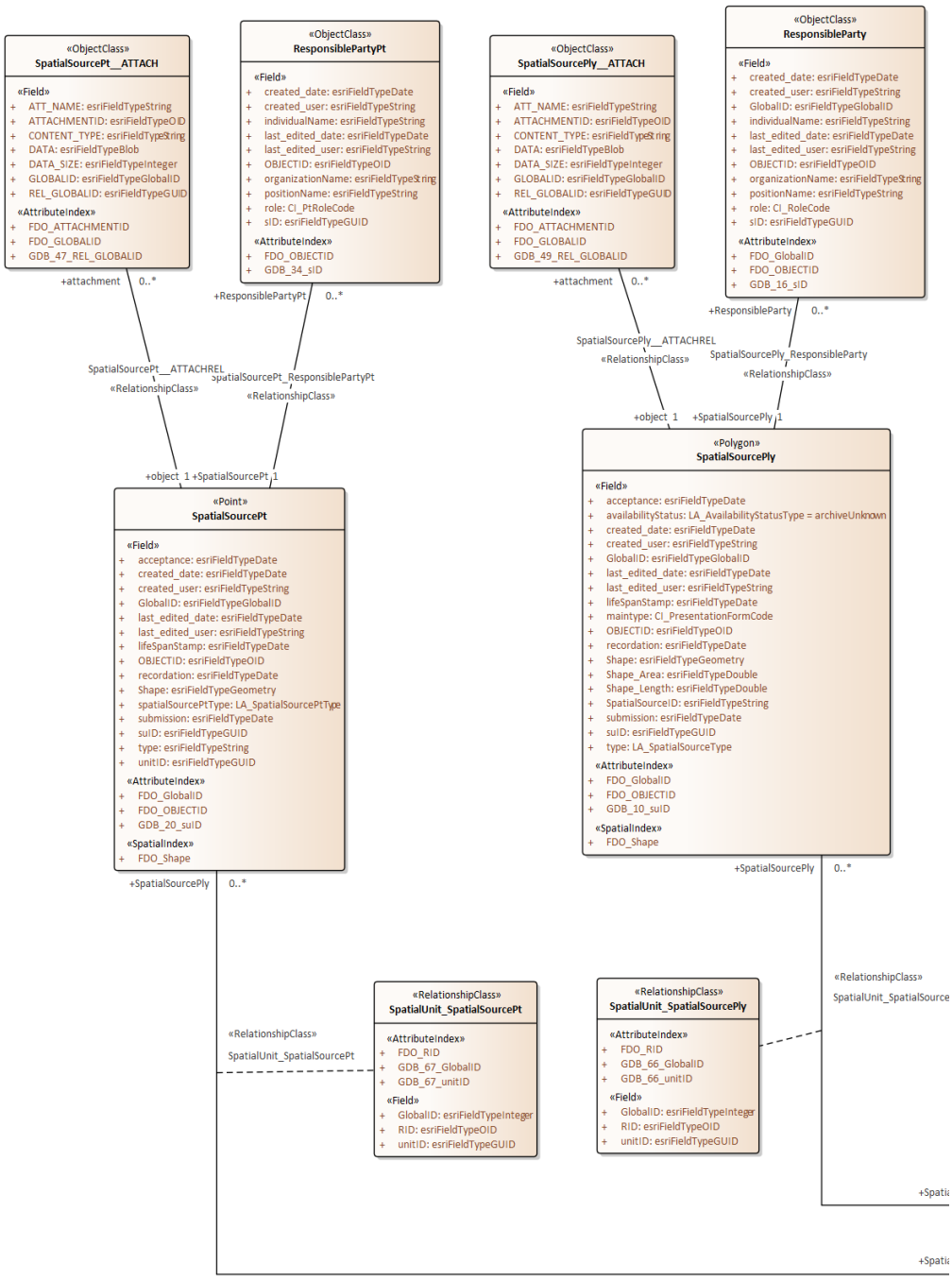

Figure 2. Spatial Source Pt and Spatial Source Ply UML Diagram

Returning to our scenario, this core LADM implementation may be used to store the incoming survey data and can be updated to reflect the land, building or unit ownership

within the Spatial Unit. Survey data itself may be brought into ArcGIS Pro and added to a geodatabase housing the core LADM implementation and either taken back out in the field to update ownership or published on the web and served through a web mapping application to be updated there.

Once the initial property boundary information has been entered in the LADM core implementation, it is migrated into a Parcel Fabric in ArcGIS Pro. The new generation of parcel fabric can be configured to reflect any data model. The Parcel Fabric data model itself consists of records, which are the equivalent to Spatial Source in this scenario, and parcel types, which are equivalent to Spatial Unit. Once a parcel fabric is created, Spatial Source and Spatial Unit may be appended into Record and Parcel Type – both of which can be renamed to reflect the LADM. Data may be entered in the parcel fabric on an ongoing basis. Having one data model such as the LADM makes this process more efficient and can be automated within the desktop software, ArcGIS Pro. Benefits to entering data into a parcel fabric early in the development process include the ability to use topological rules to identify gaps, overlaps, and other errors in the data and fix them quickly using an error inspector.

At this point in our scenario, the data for the new development is ready to be shared with the municipality for management and taxation. If the municipality has a land registry system of its own, the information collected using the LADM core implementation may be used to augment the legal record. If the municipality has decided to use the parcel fabric and LADM, the new data only needs to be added to the existing data. If not, the data created by the housing authority is in an industry standard format that can be exported to other systems as geometry and tables. Another option may be that the municipality does not have a registry system but looks to maintain information about its properties in more detail. Here an LADM country profile may be applied. The country profile in this case may make adding additional tables of information necessary to describe the type of ownership or land type, along with values that make sense to the region itself. A country profile may also be decided upon by the national cadastre. In either case, the existing data within the parcel fabric can be expanded to include these details by adding the tables and values pertinent to the country.

Property boundaries may then be managed by the municipality either within ArcGIS Pro itself or published to ArcGIS Enterprise, which web enables the parcel fabric so that it may be edited by multiple users leveraging versioned editing. Benefits to publishing a parcel fabric include having access to a powerful parcel REST API that can be used to integrate with existing registry systems and even automate some parcel editing processes (ex. merging a parcel) and will support more in the future.

Finally, a national cadastre may choose to collate all property boundaries within their country to gain a holistic view of land ownership and be able to share that with other national government organizations in a National Spatial Data Infrastructure (NSDI). If they have adopted the LADM across the country, their data is already in an accessible format to

be shared. They may leverage ArcGIS Dashboards to see how many parcels are being maintained within the country and by who, or ArcGIS Hub which enables data sharing with internal or external customers.

Conclusion

(500-1000 words)

ArcGIS and the Land Administration Domain Model support scalable collection and maintenance of land information. ArcGIS provides several applications that may be configured to support collection of property boundaries, maintenance of parcels and can be integrated with other systems. LADM is also scalable. A proposed core implementation facilitates the use of LADM in ArcGIS for field data collection purposes. Later in the management process, a country profile may be applied to collected data to reflect regional land information. These tools may be used in an Arab context to meet national needs as standards and efficiency become priorities for cadastres.

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