The Role of LADM in Configurable Geographic Information Systems

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SUMMARY

Utilizing common language within industries has long been a successful pattern within geographic information systems (GIS) to assist in identification of suitable industry specific workflows. As technology itself advances, the need for highly accessible common industry language is even more pronounced. The Land Administration Domain Model (LADM) provides this common industry language to the land administration community through the form of academic writings and diagrams. Hands on utilization of the LADM has dictated the need for interpretation as a schema. With the advancement of GIS technologies to include not only desktop oriented spatial analysis capabilities, but also mobile field collection, web based dynamic data monitoring, time enabled tracking and the promise of an upcoming three-dimensional cadastre, it is of the most importance that the land administration domain model must lend itself to ready interpretation as an easily understandable schema as well as a common language.

Before exploring the importance of the LADM schema to upholding land administration dialogue in an interconnected environment within GIS, it is important to look at the reasoning for the initial interpretation of LADM into schema within spatial software and what the ramifications are for bringing LADM into a spatial oriented architecture. One of the first implementations of LADM as working fit for purpose spatial schema format was published online by Ken Gorton of Esri in 2015 to support a pilot project including field data collection in Colombia following the peace talks which began in 2012. According to Gorton via the metadata provided on GitHub, “The LADM schema for the Colombia Pilot project was implemented […] with the purpose of representing the relevant and essential characteristics of the original schema designed by Dutch Kadaster, adding the spatial capabilities of the geodatabase and supporting the overall workflow of the data collection to be executed during the pilot.” In short, while the LADM as documented serves as an excellent road map for creating a schema, in practice some modifications are necessary to make it accessible to a technologically advancing audience.

Geographic information systems are predicated on interconnectivity, and in turn are reliant upon development of a common language or ontology, as discussed above. As hardware technology has advanced and made it possible to carry increasingly powerful portable processors anywhere, accessing data seamlessly any time has become an expectation for many around the globe. Even in places where connectivity is not reliably available, field data collection workflows revolve around sending data wirelessly back to a single source. For swift transferal of data from a mobile source to the original, a common schema is necessary. The ability to successfully transfer data resulted in the advent of dynamic dashboarding and

other visualization tools that change on the fly as new data is added, enabling decision makers to see progress, cause and effect without running computations or having to conceptualize from raw data or written reports.

Understanding the advancements that are already beginning to change the terrain of geographic information systems is critical to maintaining the LADM as the common language used within land administration – from fit for purpose to government cadastral agencies. The addition of a third (volume) and fourth (time) dimension to spatial understanding will shape the future of human interaction with land administration policy. The Land Administration Domain Model should evolve to support that advancement by becoming ever more intuitive to understand and translate to schema as the industry continues to gain insight into necessary components of the model itself through practical use.

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1. CONFIGURABLE GIS, A GEOSPATIAL INFRASTRUCTURE

This paper will discuss current trends in geographic information systems (GIS), GIS trends within the cadastral community and finally conclude with a proposed schema and path forward for successful consideration of the land administration domain model (LADM) in crafting meaningful cadastral solutions.

Geographic information systems have a colorful history of adaptation and evolution which has led directly to the state of configurability that has been realized today. The first geographic information system was theorized by Roger Tomlinson in 1969. To Tomlinson, a GIS became an effective way for him to visualize land use when studying where to expand Canadian forests and how best to manage them. From this need, a tool that allowed for not just cartography – a well-known practice in and of itself for centuries before, but a tool for dynamic analysis.

It makes sense in this light, then, that GIS was created to evolve not only with the requirements of those using the tool, but also to be tied in lock step with technological advancements of the hardware required to perform spatial analysis. As the machinery needed to perform analysis continues to advance exponentially, the capabilities of GIS also continue to advance exponentially. Instead of detailing the myriad ways that GIS has evolved over time, for the purposes of expediency, here we will explore a few pertinent trends within GIS and then identify specific capabilities within the cadastral space.

At present, technological advancements have led to the conceptualization of GIS as not only visualization or analytical tool, but as a geospatial infrastructure in and of itself. This concept is based directly in the premise that everything is related to everything else, but near things are more related than distant things (Tomlinson, 2013). If this premise is true, which it is taken to be in the GIS community, then everything has a location that can be measured. This measurement has traditionally relied upon physical visitation and documentation of a location, with the newest trends in technology that allow for everything from tiny real-time sensors placed on objects being measured to up to date aerial image capture for remote location collection. The growing options for documentation and retention of location require a robust management system, or geospatial infrastructure, to support the collection, analysis, management and sharing of large sets of often authoritative data.

Collection, analysis, management and sharing of data either internally or externally with other agencies or the public comprise the core competencies of a successful geographic system implementation. At this moment in time, the technology and geospatial infrastructure exist to support data collection that ranges from field data collection using information from high accuracy GNSS devices to aerial imagery collection with drones that enable office collection of features. Artificial intelligence is quickly providing an increasingly accurate way to extract features automatically from imagery.

Analytical tools housed within this geospatial infrastructure are used to understand trends from the data collected. Analysis may include processes that look at the quantity or quality of data collected or that look for trends within the data itself. Spatial analysis comprises its own field of study that can be aligned to the user's needs. Machine learning is making spatial analysis ever more robust with the advent of user created models that, after training, can automatically detect discrepancies or patterns in data and use that information to make predictions and identify trends using amounts of data incomprehensible to the human brain.

Management of spatial data is now fine tuned to support interconnectivity between arrays of datasets. Geographic information systems themselves have grown from being straight forward relational repositories of interactive data to being configurable to adapt to a variety of needs. Data itself can now be housed and accessed either on premises behind a firewall, in cloud environments on the web or some combination of the two. The highly available nature of this type of exposure has led to a level of interconnectivity within systems that not only enables collection and analysis of data but also enables real-time sharing capabilities. In this way, highly available data becomes a language for decision making and for communication within organizations and with the public.

At a time when data is fast becoming the most valuable resource on earth, sharing it has become a mandate not just from typical data consumers but from every day citizens. The public looks for easily digestible yet authoritative ways to view what is happening in the world around them both in the form of location visualization and metrics. Ultimately, it is for their use that a configurable GIS was conceived, with the idea that by making data capture, analysis and management as accessible as possible, more parties would begin to share their work done within this geospatial infrastructure.

2. CURRENT USE OF LADM AND CONFIGURABLE GEOGRAPHIC INFORMATION SYSTEMS

As geospatial infrastructure has evolved, the Land Administration Domain Model has also evolved from a conceptual schema to a fully realized means of communication with the ability to connect multiple systems and ideas. ISO 19152:2012 has opened the way, "to provide reference for domain ontologies of national cadastres and achieve semantic interoperability between cadastral systems," improving, "discovery, retrieval and integration of data and services… to enable involved parties, both within one country and between different countries, to communicate, based on the shared vocabulary (ontology) provided by the model." (Dubravka Sladic, 2012) This common language has provided the path forward for LADM 2.0 to incorporate further aspects of land administration such as valuation, three (volume) and four (time) dimensional modeling in addition to continuing to support fit for purpose activities from first registry to supporting spatial data infrastructure (SDI).

Various applications for valuation within the LADM have been explored through country profiles in Turkey with the Turkish Country Profile of LADM Valuation Model (Kara et. al. 2018b), Croatia (Tomic et. al 2018) and later valuation and LADM within the Netherlands were explored at the 2019 FIG Working Week (Kara et. al. 2019). Each of these explorations into extension of the Land Administration Domain Model closer to the goal of providing, "public bodies a common basis for the development of local or national databases, enable integration of valuation databases with other land administration databases and … act as a guide for the private sector to develop information technology products." (Kara et. al. 2019) As is often the case within a development cycle, often the solution is writ large at the beginning and becomes more refined upon iterative closer inspection of needs and requirements. In the case of valuation and all extensions of the Land Administration Domain Model to come, it could be inferred that the importance of the model is in the ontology itself, and that definition of terms by adding extensions eases communication between users of any technology that may support the common language as opposed to the technology itself providing means to that communication.

LADM extensions for a common language in connecting 3D applications with multiple systems have positive implications for influencing technological trends. In the case of 3D cadastre requirements in Malaysia, the a 3D LADM extension has been identified as valuable in relation to registration by providing, "3D digital representation of legal space associated with each property," as well as supporting, "efficient harmonization of 2D and 3D cadastral information from different jurisdictions," acting, "as a common language among various jurisdictions to easy share and use cadastral information with each other in digital environments." (Abbas Rajabifard et.al. 2018) Where geospatial infrastructure is concerned, the growing base of requirements for 3D within the cadastral space are informing the discussion between two complimentary but different sides of the same equation. Is it of value to be able to maintain a legal record that includes 3D data such as height and volume while also visualizing the data in three dimensions? Or will there be a mandate in the future that the legal information should be able to be derived from the three-dimensional representation itself? Through discussions using this common language of the LADM, public entities entrusted with managing a system of record such as the cadastre are empowered to communicate more effectively with product providers to come to a consensus that will meet their needs.

3. AN EXTENDABLE LADM SCHEMA FOR USE IN A CONFIGURABLE GEOSPATIAL INFRASTRUCTURE

Along with the evolution of the LADM through the exploration of extensions, technological evolution has also occurred within the space of geospatial infrastructure. In particular, commercial off the shelf capabilities have served to connect users of technology to interact on a more intimate level with their audience by configuring applications suited specifically to enable effective communication. On a heuristic level, the Land Administration Domain Model is suited to support this type of interaction. Several instances of interest in providing a common language have been cited. What does this mean from a largely spatial technological standpoint?

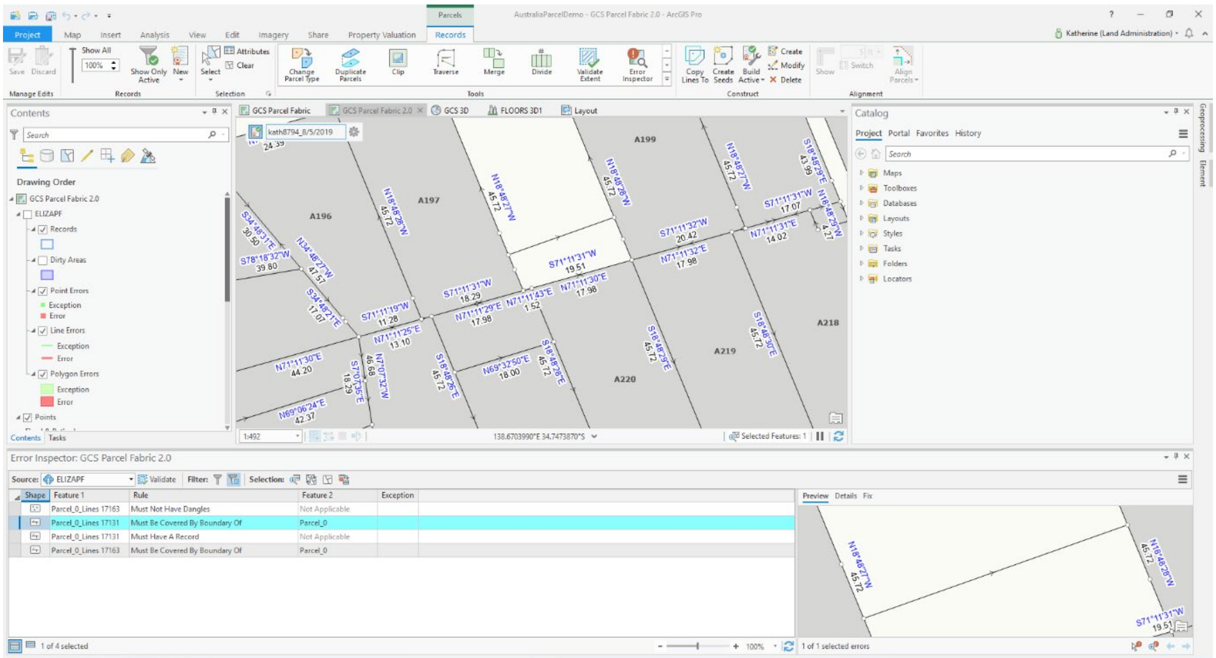
Agile development terms and workflows have grown in popularity in the last few years within the software development community, and directly influence the thought process behind product development. As noted in the *Manifesto for Agile Software Development*, the four main tenants of agile development are individuals and interactions over processes and tools, working software over comprehensive documentation, customer collaboration, and responding to change (Kent Beck et. al. 2010). Taking these tenants into account, it is not surprising that a strong need for a common language in each industry served would arise. LADM exists as a common language not only between public agencies and professionals, but also between professionals and private industry.

What does agile mean in terms of software development within the spatial world? It means that anyone can essentially configure schema components, data bases, workflows and even web applications to suit their communication needs. What does agile mean in terms of LADM within the spatial world? It could be argued that the meanings are one in the same. To this end, however, it is necessary to identify the parts of LADM that are most essential or "core" to understanding and then enabling the core schema for extension into additional realms such as valuation, 3D or 4D. This requires responsibility from both parties – from the spatial software provider to continue to innovate and from the spatial software user to learn the key workflows and configurations possible to continue to extend the schema.

In this vein, a simplified, or core, Land Administration Domain Model is being proposed. This core LADM maintains LA_SpatialUnit (also representing LA_Address) with LA_Party and LA_Administrative (representing LA_RRR) related in one to many relationships and LA_SpatialSource with LA_ResponsibleParty related in a one to many relationship. From here, extensions such as valuation, 3D or 4D may be added as needed by the country by common identifier to either LA_Spatial Unit, LA_Party, LA_SpatialSource or LA_ResponsibleParty. Additional fields and domains can be added to any table as long as the relationship through GlobalID remains intact. The simplicity of this model allows for schema configuration on top of an initial stepping stone. Advancing cadastres will be able to use the model 'out of the box' while advanced cadastres will have the technical knowledge and imperative to extend to fit their needs, while honoring the basis of common language of the Land Administration Domain Model that is held within the table relationships and capture of spatial representation and legal record (Peter van Oosterom, et. al. 2015).

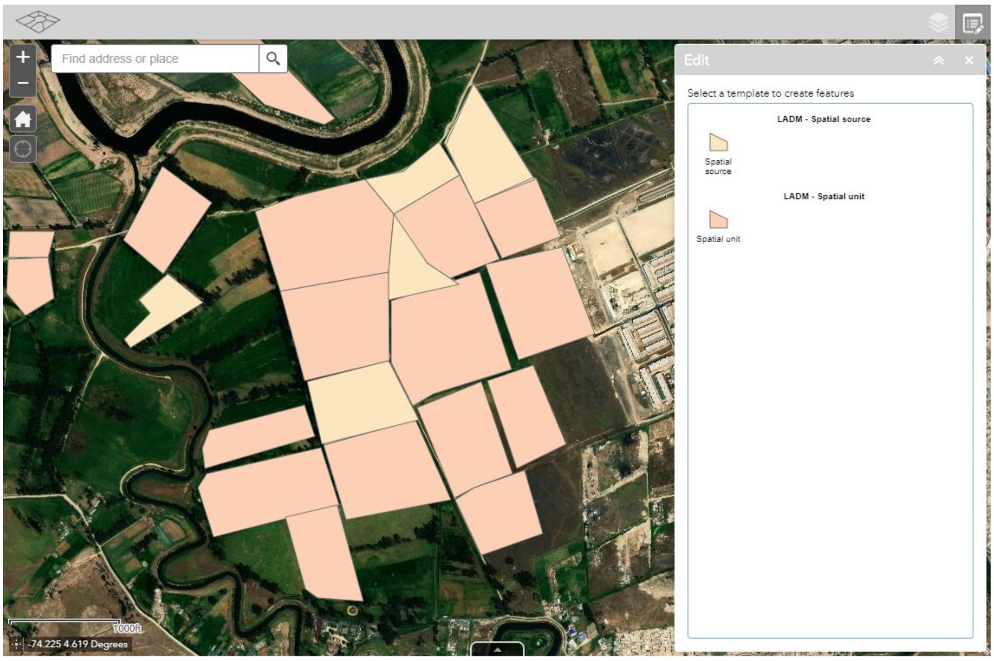
It could be argued that in this case, the legal record is taking precedence over tenure due to the condensation of address into SpatialUnit. Arguably, this simplifies the model for field data collection in a first registry type of situation where owners may often have a direct relationship to one parcel of land. If an additional address table to reflect RRR was necessary, it could always be added as an additional one to many relationship in the model of configurability. This type of simplification is often used in software development to identify the basic core of a model that works from a proven concept. The theory is that the more simple and straight forward a model is, the more efficient it will work and thus the more effective a tool for communication it will be.

In practice, this simplicity can be ascribed to several products that an end user of spatial technology may configure themselves. Data collected with the Land Administration Domain Model may later be brought into a parcel fabric that respects topological rules set by the curator of the data. For example, the topology may be set not to allow overlaps or gaps between incoming parcels and then is trained to recognize discrepancies where they exist. The parcel fabric also keeps a dynamic record of a parcel's history, ensuring LADM compliance by tracking every date and time of every change to every parcel.



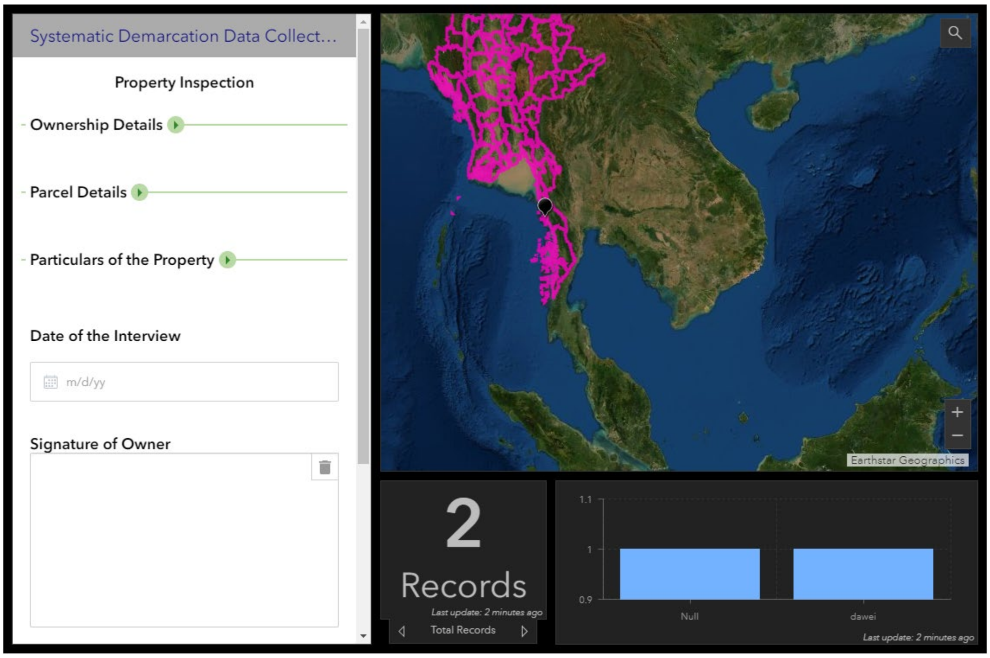
Parcel Fabric Error Inspector, ArcGIS Pro 2.4.1

Collected parcel or lot information, whether part of a topological fabric or not, can be published as a feature service using current OGC standards and shared to a web mapping application for consumption within a cadastral agency, with certain governmental entities or with the public.



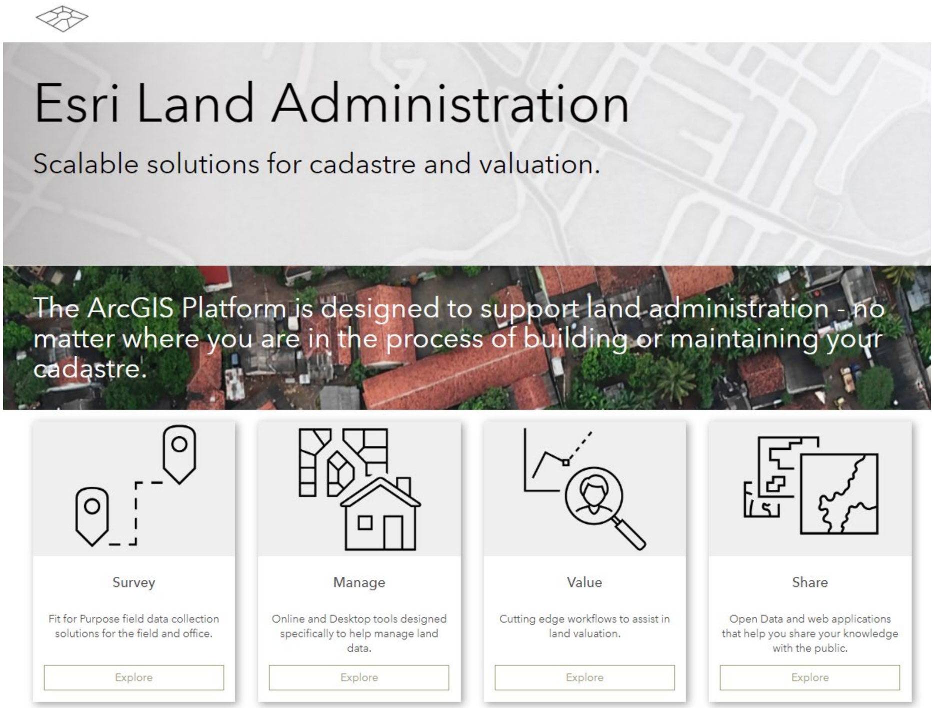
LADM Feature Service Trial Web Application, landadm-esri.hub.arcgis.com

The same feature service shared on a web mapping application may also be driving an operations dashboard showing how many parcels have been collected, by who and when.



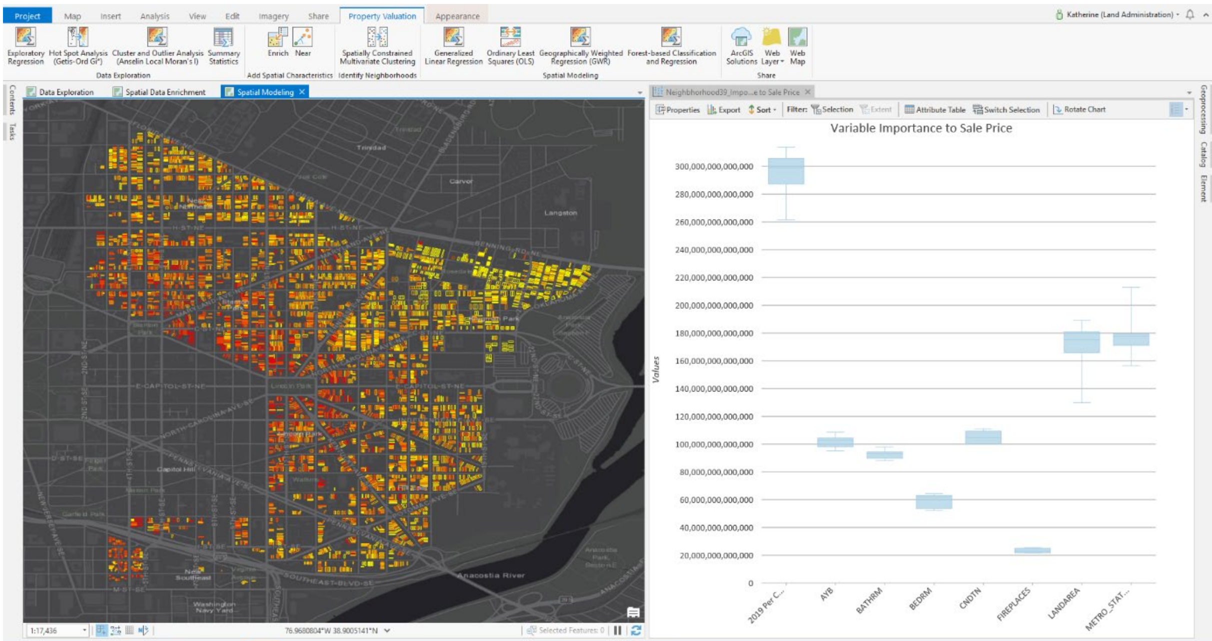
Systematic Demarcation Data Collection Trial Operations Dashboard, landadmesri.hub.arcgis.com

And any or all of the web mapping applications created could be shared to a public facing hub or portal where the general populace can interact or even respond dynamically to data collected.



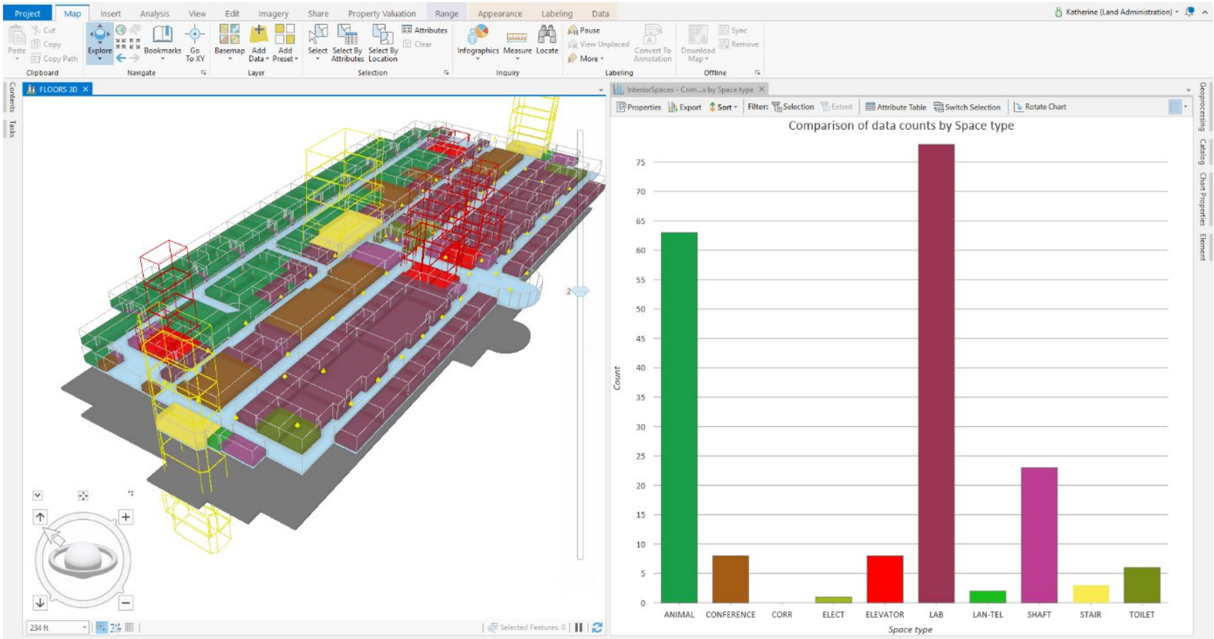
Land Administration Hub Site Landing Page, landadm-esri.hub.arcgis.com

Additionally, by joining on a common identifier, valuation data such as property sales information, valuation and property characteristics may be joined to the cadastral and tenure information allowing for validation of valuation models or even mass appraisal.



Property Valuation Analysis Results, Washington, D.C. Open Data, ArcGIS Pro 2.4.1

Multiple dimensions of a building can also be viewed when enabled with 3D data such as story height, parcel volume, all while maintaining the legal data associated with the parcel as initially collected into the core LADM.



3D Property Representation with Floor Use Charting, ArcGIS Pro 2.4.1

In conclusion, a simplified 'core' configurable or extendable Land Administration Domain Model may be instantiated to parallel core off the shelf technological configurations in the future, aligning the ISO standard with agile development patterns and enabling rapid evolution and adoption in the future. While imperfect, it may readily meet the initial need of an end user and enable them to explore spatial capabilities further due to less time spend customizing. Admittedly perhaps not the right fit for advanced cadastres, the core LADM can be configured and extended to suit the needs of each cadastre.

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BIOGRAPHICAL NOTES

Katherine Smyth obtained an MSc in Geographic Information Systems from the University of Redlands in 2013. She is currently a Solution Engineer at Esri supporting global land administration GIS users from national cadastral agencies to non-profit organizations supporting fit for purpose field collection.

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