3D Cadastres for Sustainable Development

Katie PICKETT and Matthew WOODLIEF, United States

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SUMMARY

With increasing uncertainty facing governments around the world due to climate change, rapid urbanization, and shifting economic demands, 3D economic cadastres and associated technical methodologies can support governments' sustainable development challenges and realities. 3D economic cadastres can provide better and more accurate valuation and urban and rural planning. More precise real property valuation can increase a government's tax-based capital, while holistic planning can contribute to more prepared and resilient communities.

Economic cadastres provide for the administration of real property tax policies, underpins land values, and primarily considers land markets. The addition of 3D information to an existing 2D economic cadastre, or even the creation of a new economic cadastre with 3D in-mind allows governments to plan for a more sustainable future by increasing the number of potential sources of tax revenue. The 3D valuation of an urban-based property is a holistic approach, taking into account elevation, viewshed, and volumetric calculations, while 2D valuation of the same urban property would generally rely on less holistic measures of area. 3D valuation provides for finer grained tax assessments by considering a single location of a real property in all dimensions rather than applying a blanket-rate for the entire building complex.

More accurate real property valuation can expand tax revenue providing for a more sustainable economic landscape for a government. This paper will focus on the application of 3D economic cadastres for increased sustainable development through use-case examples. Advanced 3D analytical techniques and the use of GIS will be outlined.

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1. INTRODUCTION

Governments around the world are contending with increased effects of climate change, rapid urbanization, and shifting economic demands, and 3D economic cadastres through applied 3D valuation methodology can better support countries' sustainability, development, and mitigation challenges and realities through increased tax revenue. 3D economic cadastres can provide better and more accurate valuation for urban, rural, above ground, and sub-surface real properties lending to more sustainable planning. 3D real property valuation can increase a country's, or other administrative government's, tax-based capital, while holistic planning can contribute to more prepared and resilient communities.

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More accurate property valuation can expand tax revenue providing for a more sustainable economic landscape for an administrative government. This paper will focus on the application of 3D economic cadastres for increased sustainable development through use-case examples. Advanced 3D analytical techniques and the use of GIS will be outlined.

2. 3D VALUATION

Valuation is defined by the International Association of Assessing Officers (IAAO) as, "The process of estimating the value (market, investment, insured, or other properly defined value) of a specific parcel or parcels of real estate…as of a given date..." (2022, p. 139). The purpose of real property valuation is to assess and subsequently attach monetary worth. Foundational to real property valuation is an accurate juridical and fiscal (or economic) cadastre served in a secure technical environment in which the chain of title can be traced and the assessed value is known.

A legal and accurately assessed real property can provide an owner with capital and positive financial leverage to increase financial security and gender equality. In turn, a town, county, province, or any other level of administrative government which maintains an accurate juridical and fiscal cadastre can gather taxes on real property. Taxes allow for the building, maintenance, and updating of critical infrastructure; provision of essential services and schools; and even the sustentation of technology underlying the juridical and economic cadastre. A more realized taxation base can help governments and their citizens achieve increased food security, sustainable growth, and better infrastructure development due to increased taxation revenue generation.

Traditionally, real property valuation methods have only considered the 2D. While it is true, it is better to have a legally enforceable tax base over none, would it not be better to have a more accurate and potentially larger tax revenue derived from 3D valuation? With the bevy of 3D data formats, technology, and standards (see CityGML, Indexed 3D Scene Layer, and ANZLIC), associated real property valuation methodologies should be adopted. More detailed technical representation of real property from the accuracy, precision, storage, and visualization incentivizes 3D valuation.

3D valuation can provide a more holistic understanding of real property monetary worth and increase an administrative government's taxable base. The 3D valuation of a beachside condominium, for example, could consider total beach view percentage while a 2D valuation of the same beachside condominium would not consider elevation or its viewshed. Beachside property buyers desire water views and will pay more for a water view. If the viewshed of the beachside condo is not considered using 3D technology and valuation methodology, then the value will not be as accurate.

Another multi-level tenant example is the value comparison between an upper- and basement-level urban apartment. An upper-level apartment will be valued differently from a basement-level apartment. Access to windows is minimal in basement-level apartments while upper-level apartments have more. What if an administrative government would like to better understand their sub-surface mineral rights and associate an appropriate monetary value? The use of a 3D model can assist in geophysical and geothermal understanding and mineral rights valuation. A 3D fiscal and juridical cadastre can account for both strata title and the sub-surface mineral rights examples using 3D valuation techniques, applied strata parcel, and 3D modeling geospatial technology respectively.

Increased tax revenue for an administrative government may improve their citizens' economic stability, access to healthcare and education, and provide other essential services. Consider a country with an agriculture-based land market, an up-and-coming mineral extraction economic boom, and a majority of the middle-income population. The administrative government can implement a 3D economic cadastre applying 3D valuation methodology and modeling for sub-surface mineral rights of public and private entities to increase their tax revenue. The increased tax revenue from more accurate valuation of the sub-surface mineral rights can assist the government in building more hospitals, roads, and schools and providing essential services.

3. 3D RURAL AND URBAN PLANNING

Optimizing the effectiveness of land use and the built environment in both rural and urban areas is vital to achieving equity, sustainability, and upward financial and gender-based mobility. Another example can be of an island nation and the effects of climate change. The island nation, as many are, is contending with rising sea levels and other consequences of climate change. They have a thriving tourism industry, high-value land market, and a population living below the global poverty line who depend on foreign direct investment. Using 3D valuation and an economic cadastre, the island nation is better able to understand the effects rising sea levels and increased threats of flooding may have on tourism property infrastructure and the overall land market.

The pace of urbanization leads to many challenges for cities, with informal settlements being one of the main concerns. For example, these settlements often have structures that do not meet building standards, are built on shaky foundations, and do not have adequate plumbing for sanitation. Perhaps, most importantly, the people within these settlements do not have a record of them owning property. Meaning, their entire homes can be demolished at any time. Having an up-to-date 3D cadastre can help immensely in preparing for the coming surge of urbanization. Cities can find the most suitable sites for settlements by weighing the current land ownership, land use, elevation profiles, and zoning. Going a step further, the plots can be laid out and deeds drawn up, awaiting signatures.

4. GIS TECHNOLOGY AS AN ENABLER

With the benefits of a 3D economic cadastre clearly outlined and defined it is time to implement the system. There are numerous system designs that can support 3D economic cadastres, but at the heart of each system is Geographic Information Systems (GIS). A GIS, such as ArcGIS, provides visualization, analytics, and collaboration methodologies to help ensure success of the larger cadastral system. They provide mechanisms for data storage, access, and dissemination allowing for data to be collected, maintained, and used all within a single environment which ensures that everyone who needs the data can find it and know that it is authoritative.

The first major milestone in system implementation is data review and collection. As stated earlier, there are a bevy of 3D data formats and methods for turning 2D data into 3D. A data review is essential in understanding what formats are available to the country as the time of implementation. This will also help roadmap which formats will be beneficial to seek out and use in the future as the system matures. This highlights another benefit of using GIS. GIS is generally format agnostic. They can read and consume a variety of data formats, either natively or through an Extract, Transform, and Load (ETL) process.

To establish the foundation of the 3D cadastre the data sources must be digitized and added to a system of record. The ArcGIS Parcel Fabric is an example of a parcel management tool that is built-in to an existing and stable GIS platform in ArcGIS Pro. The Parcel Fabric uses common GIS tools such as merger, split, and divide within the context of land administration. Parcel history is automatically preserved, and new parcels can be added at any time and aligned to the existing boundaries. The schema is compliant with well-known standards, such as the Land Administration Domain Model (LADM) and is flexible so additional data can be captured as attribution and used for valuation analysis. The schema contains attribution for elevation and floor information, meaning the data can be visualized in 3D, giving the assessor and real-world view of parcel relationships as shown in Figure 1.

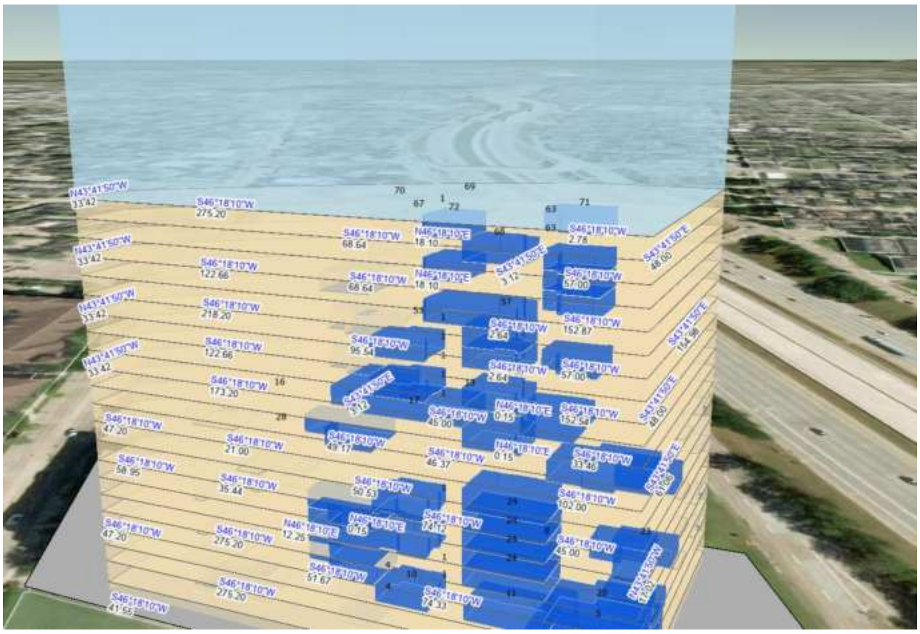

Figure 1: Condominiums have a more complex relationship than can be accurately depicted in 2D

Referring again to Figure 1, the blue space represents the air rights given to this particular parcel. Air rights are another aspect of cadastre that are hard, if not impossible, to model accurately in 2D. Using GIS technology, such as the Parcel Fabric and ArcGIS Pro, allows a city to create and maintain another source of tax income as air rights are a commodity that can be bought and sold. Some cities, such as New York City, New York has tax and building regulations that denote exactly what can be done in the space above a parcel. For example, in Figure 2, an adjacent parcel can acquire the air rights, starting at a specific elevation so they can legally build their structures higher than would be allowed by regulations. The spatial relationship between the structures and parcels involved in that type of transaction is nearly impossible to reflect in 2D.

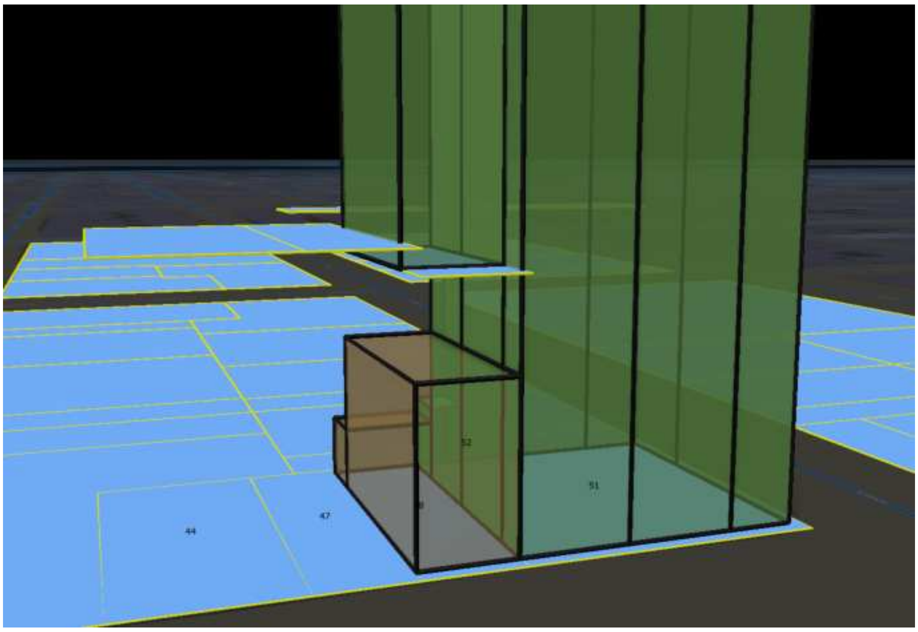

Figure 2: Air rights are a taxable commodity leading to complex spatial relationships

2D data, such as shapefiles, feature classes, and CAD dwgs can be transformed into 3D using the GIS using a process called extrusion, in which z-aware features (features with an elevation attribute) are visualized using this attribute value. Within the GIS these extruded features act like solid objects, meaning they can be used for viewshed and line of sight analysis, both of which are essential in valuating property. For example, a developing city needs to mature its tax base. Condominiums and apartments that are at a higher elevation and have a view of water or greenspace are more sought after and more valuable than those underground or with a view of a junkyard. An assessor cannot physically travel to each location to perform a comprehensive site assessment. Instead, they can use these GIS tools to help them make their valuations. This makes the benefits of using a well-established desktop GIS, such as ArcGIS Pro, readily apparent. 3D visualization and analytical methods are built-in to the software. That is to say, the software is ready to perform as soon as the data is prepared.

Using 3D ready data, the Building Information Model (BIM) for example, unlocks some additional capabilities assessors and city planners can use within the GIS. These high accuracy models contain the measurements that assessors need to make accurate tax calculations. GIS software, like ArcGIS Pro, also assists the city planner by making this data available analytics and scenario modeling. For example, the Indexed 3D Scene Layer (I3S) provides a realistic visualization that provides a better understanding of an area over something like a Digital Surface Model (DSM). However, it suffers from the same drawbacks of many imagery products, in that they only capture how the location looked at one particular moment in time. Using this type of data format in a GIS allows it to behave like any other layer, in that it can be modified to accommodate changes in the environment or model specific scenarios. Shown in Figure 3, is an I3S mesh depicting Frankfurt Germany assembled from imagery from Aerowest GMbH and processed using the nFrames SURE engine in ArcGIS. The mesh provides a high-resolution picture of reality. Figure 4 shows the same mesh being used in a viewshed analysis.

Figure 3: Frankfurt I3S Mesh

Figure 4: Viewshed Analysis using I3S Mesh

GIS also provides the capability to model new scenarios using the mesh. The city has decided to tear down the old rail depot and add in new condominiums and office space. Using GIS, BIM can be added to the scene and analysis re-run to understand how the viewshed will change with the new buildings in place of the depot. This can help city planners understand if new zoning needs to be enforced in this location and prepare for any change in the tax structure brought on by the re-zoning. Figure 5 shows how the condominiums on the top floor now have an obstructed view of the city skyline.

Figure 5: BIM in viewshed analysis

As illustrated, GIS can be used as the system of record for cadastral agencies by maintaining complex spatial relationships. GIS can also be used as the system of insight, by empowering city planners and assessors with 3D analytics. GIS can and should be used as a system of engagement as well. A full enterprise level GIS, that includes both desktop and web components is essential for establishing trust and providing transparency into the workings of government. If a government wants to generate more revenue and expand their tax base, one way to do that is publish the regulations, tax rates, and tax calculation methodology to the publish. ArcGIS enables governments to open the doors of their operation. Public trust in government makes citizens feel more comfortable by showing how tax money is spent. The enabling technology here is a Hub. A Hub functions as the window into the government. Citizens can find what they need online, access forms, and contact official departments using their mobile phone. Figure 6 is an illustration of a Hub, providing detailed tax breakdown information and a form for citizens to estimate their own tax liability if they were to buy a property.

Figure 6: Public data hubs provide transparency into tax liability and expenditures

The benefits of a 3D cadastre are numerous, but they can be achieved quicker and with a higher yield if the government can deploy GIS technology. GIS enables the government to digitize their land records, utilize information from various sources, and combine data types to aid in the decision-making process. It provides methods for engaging the public and establishing the foundation of trust that is critical for generating revenue that will allow the government to provide for the citizenry. GIS Technology makes a 3D cadastre a reality.

5. CONCLUSION

GIS serves as the technological backbone of a 3D economic cadastre. GIS functions as the system of record by not only securely storing the data but also ensuring that data is searchable, discoverable, and accessible to those that need it. Similarly, the ability to read, combine, and analyze different data formats allows the GIS to also be a system of insight that can be used by planners and assessors to more accurately conduct their analysis and review the results to ensure they are fair and equitable. Lastly, GIS can serve as the system of collaboration between the public and the administration. The open data hubs provide transparency into potential tax liability and demonstrate how the tax revenue is being utilized which enhances the public trust of the system.

Governments can implement 3D economic cadastres to mitigate effects of climate change, ensure sustainable urbanization, and to plan for shifting economic demands. Valuation for multiple types of real properties leveraging 3D economic cadastres can support more sustainable and effective land use planning by increasing the number of potential sources of tax revenue. 3D real property valuation can provide a more holistic and accurate tax base while increasing the overall capital to positively contribute to more prepared and resilient communities.

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CONTACTS

Katie Pickett
Esri
8615 Westwood Center Dr
Vienna, VA
22182
United States of America
Tel. +1 703 506 9515
Email: kpickett@esri.com
Web site: www.esri.com

Matthew Woodlief
Esri
710 N Tucker Blvd
Ste. 600
St. Louis, MO 63101
United States of America
Tel. +1 636 949 6620
Email: mwoodlief@esri.com
Web site: www.esri.com