Creation of 3D City Models and Sustainability of the Project; Türkiye Example

Zeynep BAYRAMOĞLU, İsmail DURSUN, Mustafa ASLAN, Mehmet Zeki ADLI, Türkiye

Key words: 3D Cadastre; Sustainability; Smart city

SUMMARY

In today's world, 3D city models play a significant role in areas such as urban planning, land management, and disaster management to make cities more liveable and effectively manageable. To achieve this goal, numerous 3D data management standards have been established worldwide. In Turkey, the CityGML standard is preferred for 3D modelling; however, there are some shortcomings in its application to the Turkish system. Therefore, the GDLRC-CityGML standard has been developed, and an information system has been established to manage 3D city models in accordance with this standard. Within the scope of the project, architectural projects in the GDLRC inventory are scanned, integrated with aerial photographs, transformed into 3D models, and presented on the web in their actual locations. The aim is to complete the modelling of all architectural projects in the land registry inventory by the year 2026. However, it is crucial that the 3D models of future structures, controlled by the relevant institution, be integrated into the system without adding an additional burden to cadastral and registration efforts. In this context, 3D data in GML format, which includes details such as world coordinates, province, district, neighbourhood, block and parcel information, is transferred to the municipality, land registry and cadastral units through the developed system, and registration is carried out by manual and automatic controlls.

ÖZET

Günümüzde kentlerin daha yaşanabilir olması ve etkili yönetilebilmesi için 3 boyutlu kent modelleri, şehir planlama, arazi yönetimi, afet yönetimi gibi alanlarda önemli rol oynamaktadır. Bu amaçla dünya genelinde birçok 3D veri yönetimi standardı oluşturulmuştur. Türkiye'de 3d modelleme için CityGML standardı tercih edilmitşir, ancak bu standardın Türk sistemine uygulanmasında bazı eksiklikleri bulunmaktadır. Bu nedenle, TKGM-CityGML standardı geliştirilmiş ve bu standartla uyumlu olarak 3 boyutlu şehir modellerini yönetmek amacıyla bir bilgi sistemi kurulmuştur. Proje kapsamında, TKGM envanterindeki mimari projeler taranarak ve hava fotoğraflarıyla entegre edilerek 3D modellere dönüştürülmüş ve gerçek konumlarında web üzerinde sunulmaktadır. 2026 yılında tapu envanterindeki tüm mimari projelerin modellenmesinin tamamlanması amaçlanmaktadır. Ancak gelecekte üretilecek olan yapıların, ilgili kurum tarafından kontrol edilen 3 boyutlu modellerinin, kadastro ve tescil çalışmalarına ek yük getirmeden sisteme entegre edilmesi önemlidir. Bu kapsamda, dünya koordinatları, il, ilçe, mahalle, ada, parsel bilgileri gibi detayları içeren GML formatındaki 3 boyutlu veriler geliştirilen sistem üzerinden belediye, tapu ve kadastro birimlerine aktarılmakta ve manuel ve otomatik kontrolleri yapılarak tescil işlemi yapılmaktadır.

Creation of 3D City Models and Sustainability of the Project; Türkiye Example

Zeynep BAYRAMOĞLU, İsmail DURSUN, Mustafa ASLAN, Mehmet Zeki ADLI, Türkiye

1. INTRODUCTION

In terms of sustainable land management, the relationship between land and people is an important topic that needs to be investigated worldwide. Many countries around the world create cadastral maps based on 2-dimensional cadastral systems in their land management systems. This complicates the physical and legal management of cities and leads to misunderstandings regarding property rights (Stoter et al., 2019). Due to factors such as climate change and uncontrolled population growth, the vertical dimension of the land is increasingly utilized as the density on the land intensifies.

The extensive use of vertical settlements necessitates accurate data management, including building height, slope, and other topographic characteristics. According to the cadastre visions of 2014 and 2034, the future cadastre will be three-dimensional and connected to real estate information (Polat et al. 2015). In light of this, a 3D cadastre needs to include both the physical and legal 3D representations of things (Atazadeh et al., 2016; Sürmeneli et al., 2020).

Sustainable development aims to use natural resources and environmental systems in a balanced manner in order to meet the requirements of present and future generations. Preparation of land ownership data to measure metrics relevant to the SDGs: The United Nations' Sustainable Development Goals (SDGs) are a primary driver of global geospatial information harmonization. This method, which combines economic growth, social justice, and protecting the environment, attempts to achieve balance (SDG, UN). Sustainable development, when incorporated into urban planning and management processes, provides a crucial foundation for cities' long-term health and prosperity (Rajabifard, Agunbiade, et al., 2018). Three-dimensional cadastral systems help to manage resources more effectively and reduce environmental impact by giving more precise information on urban planning and land usage.

Emerging technologies and the growing importance of spatial data management highlight the need for an intersectoral approach in the acquisition, maintenance, reuse, and distribution of 3D data. However, the execution of this comprehensive approach causes specific functionality challenges in collaborative processes, which necessitate the introduction and implementation of standards (Lemmen, Oosterom et al., 2017; Alkan & Sürmeneli, 2020). Collaboration on 3D data across industries decreases information flow inconsistencies, improves design and data collecting efficiency, and customises data quality to meet requirements. This method improves spatial data management by encouraging cross-sector collaboration and leading to the development of more effective solutions.

In view of all these developments, the General Directorate of Land Registry and Cadastre (GDLRC) launched the "3D City Models and Cadastral Bases Integration Pilot Project" in the province of Amasya with the goal of strengthening the nation's technological infrastructure and updating and improving cadastral data. Following that, the project's sustainability was extended across the entire country.

2. Türkiye's 3D Studies and Sustainability

GDLRC has completed the 2D cadastre since 1924, measuring 58.5 million parcels. However, in light of technical advancements, the "3D City Models Production and 3D Cadastral Bases Project" was started in 2020 to more effectively control the geometry of buildings and independent parts. The establishment of the GDLRC 3D City Models management Information System, which covers the administration of three-dimensional data that GDLRC has produced or will produce, is the goal of this significant project.

Within the scope of the project, architectural projects found in the land registry office inventory are scanned by companies through the tender process. These projects are vectorized, and three-dimensional models are created, incorporating room and area information. Simultaneously, those that meet the accuracy criterion are coordinated in the ITRF-96 Datum by comparing the architectural models with the real building models that were created using oblique aerial photos.

After all architectural projects in the land register inventory are completed by the end of 2026, it will be essential to update the project within the regular cadastre and registration procedures without adding to the effort. The understanding of the difficulties encountered in incorporating new architectural projects into the system is significantly affected by the legal notions of condominium ownership and floor easement. These ideas regulate the rights of flat owners with regard to the particular areas of buildings that they own. Condominium ownership means that each apartment has its own private property as soon as the project is finished, but floor easements guarantee that the building on the land is registered in the title deed during progress. Pre-construction building integration into the system will not only improve project sustainability but also save time and resources for people in general.

The urbanization process in Turkey has accelerated especially since the 1980s, and during this period a significant gap has been created between official ownership records and actual usage status. However, despite this situation, legislation such as the Turkish Civil Code and the Zoning Law have focused on the registration of legally compliant structures, making the difference between official property records and actual usage status clear. This bottleneck was resolved by allowing the registration of structures built without compliance with zoning regulations in the land registry after the last additional regulation made in Article 32 of Law No. 3194 on Urban Planning in 2020. Following this regulation, the General Directorate of Land Registry and Cadastre (GDLRC) initiated a new model to transfer the country's building stock to registries and maps automatically.

In this regard, the Circular No. 2017/6 of the Ministry of Environment, Urbanization and Climate Change has added a provision stipulating that three-dimensional digital building models prepared during the approval process of architectural projects in floor easement/condominium establishment transactions should be sent to the land registry office in a secure electronic environment. Cadastre Law No. 3402 and Presidential Decree No. 4 contain regulations on issues such as spatial information system infrastructure, map production monitoring centre, evaluation of real estate and electronic land registry (Turkish Grand National Assembly, 1985). In addition, 3D Digital Building Model, according to the circular numbered 2021/2 of the Ministry of Environment, Urbanization and Climate Change, three-dimensional digital building models prepared as a part of architectural projects can be used by municipalities and other authorized institutions in accordance with the determined standards. It includes a regulation that requires it to be sent to GDLRC in a secure electronic environment. These regulations constitute the legal basis for the sustainability of the three-dimensional city models project.

The project started with the creation and publication of GDLRC production standards for the production of 3D building data. Subsequently, a two-stage verification method was adopted to monitor and verify the 3D data production. In the first stage, data produced is verified using a dynamic checklist, and building summary forms are generated. Following this, the data undergoes a manual verification stage. Verified and registered 3D data is then transferred to the GDLRC 3D Database. This database has an infrastructure that supports different coordinate reference systems and incorporates the CityGML data model structure.

The project also includes integrations at the national level, integrating 3D data models with the Turkish National Addressing System (MAKS), Land Registry and Cadastre Information System (TAKBİS) and Webtapu.

2. METHODOLOGY

The implementation of the sustainability of the three-dimensional urban models project is fundamentally composed of stages such as production, verification, registration, storage, presentation, and sharing (Figure 1).

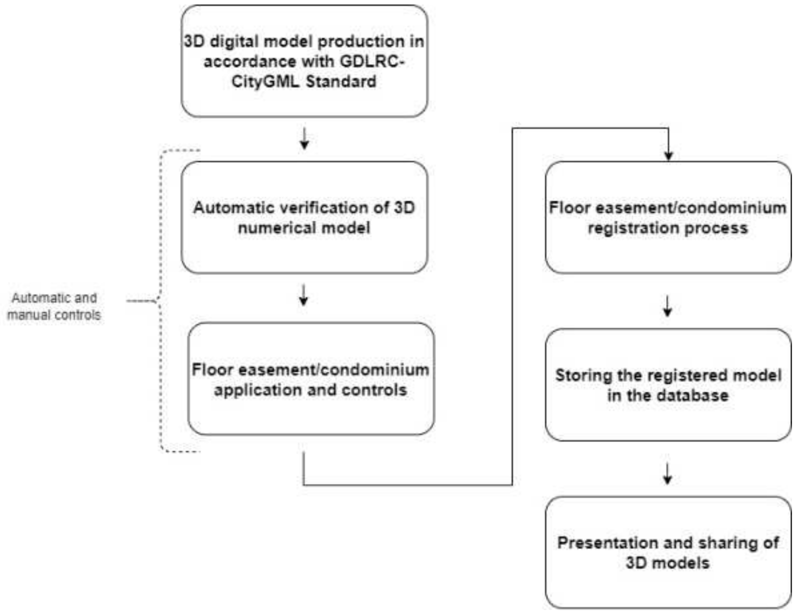

Figure 1: Stages of the project

2.1 Production of 3D model

2.1.1 GDLRC-CityGML Standard

CityGML is an open data model and XML-based format used to represent and share city models in 3D. This standard defines virtual 3D models of objects such as buildings, roads, green spaces, and waterways in the city, enabling detailed and comprehensive analyses in urban planning, geographic information systems (GIS), and related fields (CityGML, OGC). The general objectives of CityGML include representing 3D city models, standardizing data exchange and sharing, enriching with semantic information, and providing dynamic Level of Detail (LOD). These goals aim to facilitate the effective management of city-related data and ensure consistent data sharing across different applications.

However, there are potential disadvantages in the integration or implementation of the model with the Turkish Land Registry System. The lack of a direct correspondence for independent units, particularly in the management of independent units as specified in the Turkish Civil Code and Condominium Ownership Law, leads to deficiencies. According to the Turkish legal system, the effective management of independent units is critically important for regulating relationships among property owners and ensuring the healthy operation of immovable properties. Therefore, strengthening the representation of independent units in CityGML, especially in compliance with Turkish legal norms, is a significant step towards addressing this fundamental deficiency in the system.

ISO, OGC, and FIG conduct research on the implementation of 3D cadastre. In 2001, under the guidance of FIG, 3D cadastre was first discussed internationally, and support was provided for the development of 3D cadastral systems that each country could choose based on its own needs. Additionally, they recommended the use of standards to create and adopt a common concept and terminology when developing 3D cadastre systems (Döner et al., 2011).

The GDLRC-CityGML model, developed to suit the Turkish land registry and cadastre system, includes special objects and classes added to the existing CityGML data model. For example, since there is no specific category for independent units in the building class of the CityGML data model, the geometries of independent units have been integrated into the existing CityGML data model as "GenericCityObjects," and attribute data is stored as "GenericAttributes" (figure …). The features of the customized GDLRC-CityGML standard have been shared on the institution's website, ensuring that manufacturers can follow them. Throughout this process, different versions of the model have been developed and shared through ongoing pilot projects.

```
<gen:GenericCityObject gml:id="BB_f1344fe9-5d7c-48f3-83d7-
aaa0590f0d5c">
      <!--Bağımsız Bölüm Meta Data-->
      <gml:name>Bağımsız Bölüm 1</gml:name>
      <gen:stringAttribute name="independentSectionNumber">
        <gen:value>1</gen:value>
      </gen:stringAttribute>
      <gen:intAttribute name="takbisPropertyIdentityNumber">
        <gen:value>192CAA50C279F</gen:value>
      </gen:intAttribute>
      …
      …
      …
```

3.1 Validation

The validation of GDLRC-CityGML data is critical for maintaining and improving data quality, increasing interoperability, ensuring standard compliance, and supporting informed decision-making in urban planning and related fields.

3.1.1 Automatic validation

As part of the sustainability of the project, the models produced are initially checked through the web application developed by GDLRC. During the verification process, a total of 400 schematic, geometric, and topological validations are performed. Some of these validations controls; the presence of at least one floor and one independent section in the building, completeness of building ID, parcel, block, and building number values, confirming the definition of the coordinate system and examining connections between objects for intersections, proximity of rooms to independent sections, ensuring no gaps exist between room walls and independent sections.

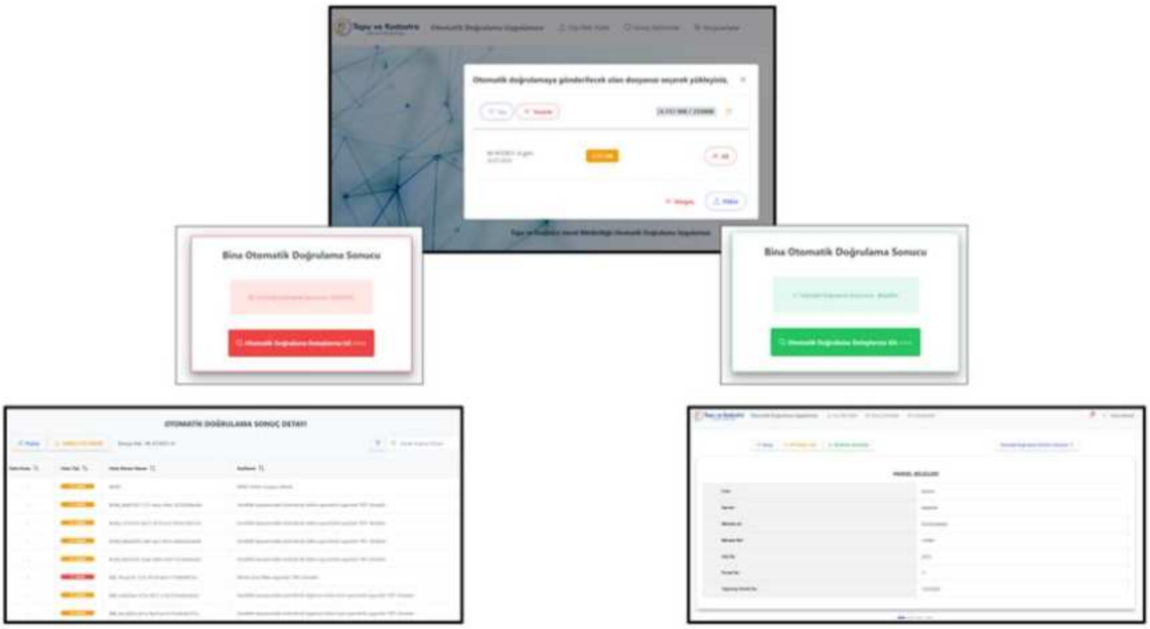

Figure 2: Outcomes of the verification process

There are two possible outcomes from the verification process: successful and failure (Figure 2). When a verification error occurs, error codes are provided, and the issue has to be recreated while keeping production standards and error codes in account. The manufacturer receives a special verification code from the system to utilise in the following stages if the process is successful. The upload procedure can be repeated to create a new verification code in case the original is misplaced or the model has to be altered.

The method generates a building summary form via the system for buildings for whom a verification code has been obtained (Figure 3). The building summary form includes information about the building, including its floor plan, coordinates, block-parcel number of the parcel on which it is situated, lists of independent sections, and architectural projects of those sections that are created from three-dimensional models.

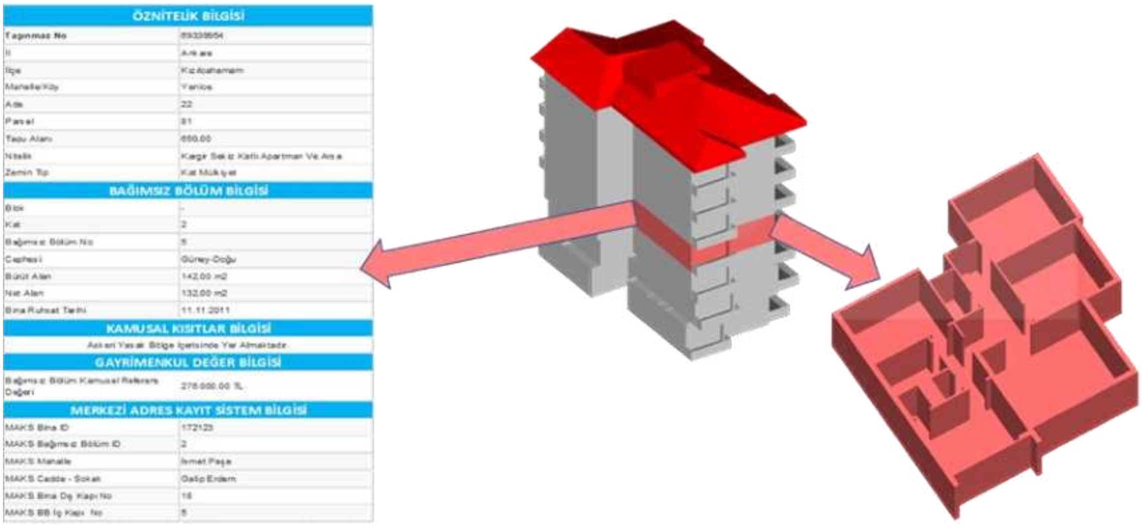

Figure 3: Building summary form

3.1.2 Floor easement/condominium application and manual controls

Obtaining the verification code is followed by the application for floor easement/condominium to the municipality. Municipalities are administrative units that carry out local government duties and provide local services over a specific geographical area, such as a city or town. Although floor easement/condominium registration procedures are carried out in land registry offices, since procedures such as approval of architectural projects and issuance of building permits are carried out by municipalities, these documents are sent to the land registry directorate by the municipalities through the Webtapu application, which is a secure electronic platform.

Webtapu is an information system developed by GDLRC that makes it convenient for all citizens, registered companies and public institutions to track and manage their real estate over the internet, and has added many features for the business and transactions of public institutions (Figure 4).

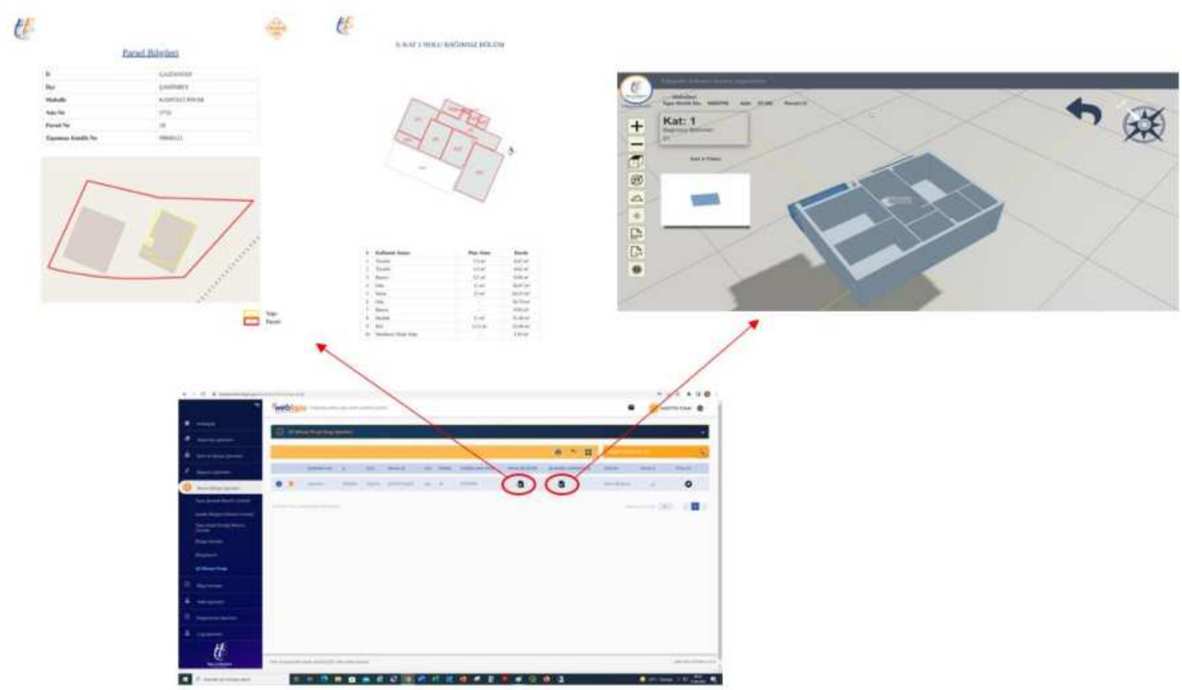

Figure 4: Webtapu application

Citizens apply to the municipality with the verification code, architectural project of the building, building application project, building permit, digital building application project, management plan and layout plan according to the requests of the municipalities. Municipality personnel perform manual checks in the process, including verifying the alignment of the 3D Digital Building Model with the approved architectural project, confirming the consistency between the validation report (building summary form) and the architectural project.

If an error is found after the check, the application must be rejected and the model must be reproduced. If there is no error, the required documents are uploaded within the Webtapu application and the approval process is carried out.

Documents uploaded to the Webtapu application by the municipalities are transferred to the MEGSSİS application (Figure 5). The Cadastre Directorate is the government agency that keeps official records of land ownership, boundaries and other land information. Spatial Real Estate System (MEGSİS) is an application developed to digitally collect cadastral data and harmonize and present it with land registry data.

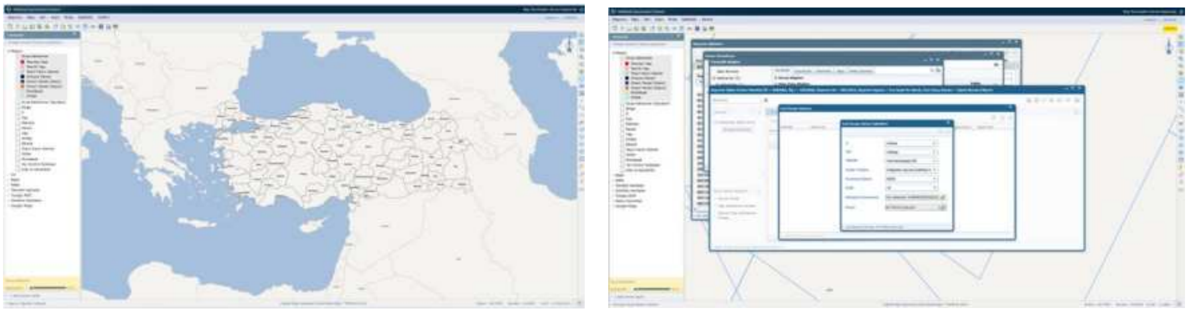

Figure 5: MEGSİS application

The cadastral directorate personnel manually conduct cadastral checks on documents received through the application. Key checks include comparing the building boundaries in the 3D Digital Building Model with those in the building application project and defining the building boundaries in the system.

If a mistake is discovered during the control, the application is rejected by the system; otherwise, the authorised individual creates the GDLRC-GML file, which contains the building's floor plan information, and uploads it to the MEGSİS programme. The land register office receives the completed application from the cadastre directorate for registration.

3.2 Registration of models

Files transferred via Webtapu and MEGSIS applications are transferred to TAKBİS software, which is the land registry office application. It is an e-government project created to transfer the property data in the Land Registry and Cadastre records throughout Turkey to the electronic environment, to carry out the transactions electronically, to track and control them effectively and quickly. At this stage, the registration process is completed by checking the list declaration information form and property rights of the building.

3.3 Storage of the models

CityGML supports 3D modeling of cities by providing detailed and comprehensive data models, but this feature can cause data files and databases to be large (Ledoux et al., 2019). This can increase storage, transmission and processing costs, and the size and complexity of data sets can lead to performance issues in some applications. GDLRC3D platform aims to overcome these disadvantages by offering the ability to successfully convert 3D building data into CityJSON, KML, OBJ, Collada, 3Dpdf formats thanks to special conversion services. In this way, the integration and processing of data sets in different formats is carried out more effectively.

3.4 Representation and sharing of the models

Once the registered and stored data are processed, the models are presented on the website. Building stock can be tracked and classified according to the models produced on the relevant web page. In this context, the structures were classified under 3 main headings, and then the analyses were supported with subclasses.

Figure 6 : Classification of the modelled building (Green: registered, Blue: unregistered, Red: public buildings)

Legal regulations for the sharing of produced models have not been completed yet and studies are continuing. Great importance is given to the confidentiality of personal data, especially in the presentation and sharing of models. Presentations are planned to be held between the relevant parties, secured by confidentiality measures. With this approach, GDLRC, the responsible institution, aims to provide both an effective and safe sharing process.

4. RESULT

The system with the three-dimensional city models sustainability project included 500 buildings. The project's scope is being gradually expanded, and changes are being made to the GDLRC-CityGML standard to align with system enhancements and requirements based on real-world scenarios.

As a result, the three-dimensional information system produced offers a wide range of usable infrastructure, from disaster management to fair taxation, from municipal services to smart cities. In order to be used effectively in these comprehensive projects, information will be shared with relevant institutions, organizations and citizens, so that the benefits of the project can be felt more effectively throughout society. By collaborating on a common data set, data duplication will be minimized, reducing costs and providing rapid access to secure, accurate data. In this way, it will be possible to develop more effective and sustainable solutions in various sectors across the country.

REFERENCES

Alkan, M., & Sürmeneli, H. G. (2020). 3D cadastral standard definition and development using international standards for Turkey cadastral system. *Journal of Geodesy and Geoinformation, 7(1), 70–85. https://doi.org/10.9733/jgg.2020r0005.e*

Atazadeh, B., Kalantari, M., Rajabifard, A., Champion, T. & Ho, S., (2016). Harnessing BIM for 3D Digital Management of Stratified Ownership Rights in Buildings. *FIG Working Week 2016: Recovery from Disaster, Christchurch, New Zealand 2-6 May 2016*

Cadastre 2034, Powering land and real property. *Cadastral reform and Innovation for Australia – A National Strategy, 2015*

Döner F., Bıyık C. & Demir O. (2011) Dünyada Üç Boyutlu Kadastro Uygulamaları, *Jeodezi ve Jeoinformasyon Dergisi, 104.2, 53-59, Oct. 2011*

Ledoux, H., Arroyo Ohori, K., Kumar, K., Dukai, B., Labetski, A., & Vitalis, S. (2019). CityJSON: A compact and easy-to-use encoding of the citygml data model. *Open Geospatial Data, Software and Standards, 4(1). doi:10.1186/s40965-019-0064-0*

Lemmen, C.; van Oosterom, P.; Kalantari, M.; Unger, E.-M.; Teo, H.C. & Zeeuw, K. Further Standardisation in Land Administration. *In Proceedings of the Annual World Bank Conference on Land and Poverty, Washington, DC, USA, 20–24 March 2017*

Polat, ZA, Üstüner, M., & Alkan, MN (2015). Kadastro 2034 Vizyonuna Giden Yolda: Türkiye'nin Kadastro 2014 Performansı. *FIG Working Week 2015 From the Wisdom to the Ages to the Challenges of the Modern World, Sofya, Bulgaristan, 17-21 Mayıs 2015*

Rajabifard, Agunbiade, Kalantari, M., Yip, K., Atazadeh, B., Badiee, Isa, D., Adimin, M., Chan, K., Aien, A., Olfat, H., Shojaei, D., & Anaraki. (2018). An LADM-based Approach for Developing and Implementing a National 3D Cadastre – A Case Study of Malaysia. *7 Th International FIG Workshop on the Land Administration Domain Model, 11-13 April 2018, Zagreb, Croatia*

Stoter, J.E., Ho, S., & Biljecki, F. (2019). Considerations For A Contemporary 3d Cadastre For Our Times. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*.

Turkish Grand National Assembly. (1985). *Law on Land Registry and Cadastre Services (No. 3402). Official Gazette, No: 18933, July 13, 1985*.

CityGML. Open Geospatial Consortium. *(Access Date: 2023, January 20). Retrieved from: https://www.ogc.org/standard/citygml/*

United Nations. (Access Date: 2023, January 20). The 17 goals | sustainable development. *Retrieved from: United Nations. https://sdgs.un.org/goals*

BIOGRAPHICAL NOTES

Zeynep Bayramoğlu is a Geomatic Engineer working at General Directorate of Land Registry and Cadastre in Turkey. She obtained a master's degree in 3D Cadastre and Land Administration Systems from the University of Edinburgh in the United Kingdom. Additionally, she earned a master's degree in remote sensing and geographical information systems from Yıldız Technical University in Turkey.

CONTACTS

Zeynep BAYRAMOĞLU
General Directorate of Land Registry and Cadastre
Dikmen caddesi No:14 Bakanlıklar, Çankaya
Ankara
Türkiye
+90 312 551 44 56
tk46536@tkgm.gov.tr
https://www.linkedin.com/in/zeynepbayramoglu/