Extending NSDI with LADM Valuation Information Model and Expert Opinions to Calculate Score Values of 3D Real Estate

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Key words: Land administration, Real estate valuation, SDI, 3D building, LADM Valuation information, smart city.

SUMMARY

There is a need for high quality, reliable and up-to-date database management systems to determine sustainable property management policies in smart cities. The database management systems capable of storing 2D and 3D spatial information can be effectively used in smart city applications related to many data themes such as buildings, cadastre, transport, land use, etc., considering the needs of applications including property valuation. The property valuation process involves an impartial assessment of the various elements that influence the potential value of a property that is not only rights, restrictions, responsibilities (RRRs), condition of real estate, spatial planning status and constraints but also environmental, geographical, location and socio-cultural information. While traditional cadastral systems provide legal information about properties with 2D geometric information, 3D building and dwelling models can provide more meaningful data for GIS analysis that can be used to increase the accuracy of real estate valuations. If a country has an effective National Spatial Data Infrastructure (SDI) with 3D support, it can be used to link different data themes, such as buildings, cadastre, land use, addresses, etc., that are required in valuation processes. However, to meet today's 3D real estate valuation needs, an extension to NSDI may be required for property valuation registers. ISO/DIS 19152-4 *Valuation information* specifies the characteristics and semantics of valuation registers maintained by public authorities. It covers all administrative valuations and all input and output data within the valuation processes.

The purpose of this study is to extend the NSDI of Türkiye with ISO 19152-4 Valuation information and local value affecting factors to cover all the characteristics required in the 3D real estate valuation, and to implement the developed data model. The developed data model is tested using real 3D dwelling data, and data (value affecting factors) collected through a questionnaire. The scores of each 3D condominium unit are calculated based on the questionnaire answered by the valuation experts.

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1. INTRODUCTION

Real estate information is intricately connected to multiple facets of urban progress, encompassing economic advancement and quality of life (Geipele et al., 2014; D'Acci, 2019). As the backbone of sustainable urban management, precise and standardised real estate information is essential to ensure successful urban planning, infrastructure development, environmental sustainability, economic development, and real estate valuation (Rajabifard et al., 2013; Dawidowicz et al., 2014; Rogatnev et al., 2020). (Bovkir and Aydinoglu 2018; Janecka, 2019).

Standardizing models in real estate information management is crucial for improving the dependability, uniformity, and usefulness of data, which is vital for making well-informed decisions in urban planning (Aydinoglu and Bovkir, 2017). As a result, application of modern technologies, online platforms, and boosted real estate valuation methodologies can revolutionise the real estate market, offering prospects for more sophisticated management and decision-making in the context of smart cities (Ullah et al., 2018; Apanaviciene et al., 2020; Sisman and Aydinoglu, 2022).

Smart and sustainable urban planning, development and implementations are highly dependent upon the efficient administration and utilisation of three-dimensional (3D) data (Biljecki et al., 2015; Isikdag et al., 2015; Janecka and Karki, 2016; Alavipanah et al., 2017; Apeh and Adbul Rahman, 2023). Regarding the fields of cadastre and real estate, 3D data acquisition, modelling, and visualisation technologies have greatly increased utilization with a particular importance (Kara et al., 2020; Suwardi et al., 2022). Using 3D Geographic Information Systems (GIS) allows for in-depth analysis in evaluating property characteristics and values through advanced geographic analysis such as visibility (Kara et al., 2020).

The real estate valuation process involves an impartial assessment of the various elements that influence the potential value of a property (Bovkir and Aydinoglu, 2018; Aydinoglu et.al., 2022; Yalpir et al., 2021), which include not only rights, restrictions, responsibilities (RRRs), condition of real estate, spatial planning status and constraints but also environmental, geographical, locational and socio-cultural information (Kara et al., 2020; Sisman and Aydinoglu, 2022). For example, access to urban functions, energy performance, solar potential, view characteristics of a real estate, together with local characteristics are of great importance for effective property valuation. A detailed data model is required that clearly organises all the required information. There is a need for high quality, and reliable 2D/3D spatial information that can be effectively used in smart city applications related to many data themes such as buildings, cadastre, transport, land use, etc. If a country has an effective National Spatial Data Infrastructure (SDI) with 3D support, it can be used to link different data themes, such as buildings, cadastre, land use, addresses, etc., that are required in valuation processes. The ISO 19152 Land Administration Domain Model (LADM) is the only

standard that considers links between cadastral, building, land use and property valuation registers, it makes sense to use the LADM when extending an NSDI. The LADM defines a common terminology for land administration and includes both support for 3D representations of spatial units and a seamless integration of 2D and 3D spatial units. One of the new parts of the LADM will most probably be *ISO 19152-4 Valuation information* which specifies the characteristics and semantics of valuation registers maintained by public authorities.
The main objective of this paper is to extend the NSDI of Türkiye with *ISO/DIS 19152-4 Valuation information* and value affecting factors to cover all the characteristics required in the smart city applications and 3D real estate valuation, and to implement the model for calculating the parametric value scores of 3D buildings and condominium units. For the case study, factors affecting real estate value were determined by considering the designed models, literature reviews and existing data content. By using one a Multi-Criteria Decision Analysis (MCDA) method, the parametric value scores were calculated based on GIS for each condominium unit in five different categories and a consolidated parametric value score can be used to support real estate valuation.

2. DESIGNING REAL ESTATE VALUATION INFORMATION MODEL

The management of real estate plays a crucial role in implementing fair, comprehensive, and rational urban policies, which are vital for the sustainability of urban services and the effective administration of properties in a specific area from multiple perspectives (Hely and Antoni, 2019). When examining the current real estate management landscape, it is evident that information regarding parcel details, legal restrictions, zoning regulations, and building characteristics are stored in different data repositories.
Real estate appraisal is an essential aspect of real estate management, serving a wide range of purposes such as expropriation, tax assessment, zoning initiatives, insurance, value-oriented transactions, and urban redevelopment (Kara et al., 2021; Yalpir et al., 2021; Sisman and Aydinoglu, 2022). The accuracy, consistency, and reliability of operations within this wide field of real estate valuation are closely tied to the quality, thoroughness, and timeliness of the data used (Aydinoglu and Bovkir, 2017). Valuation procedures in real estate encompass various essential factors. These factors encompass the geometrical, locational, and physical attributes of the property, as well as the legal aspects related to ownership and formal inventories that impact market prices (Kara, 2021).
In this study, a comprehensive conceptual data model has been developed, which is specifically designed for open data management in the field of Real Estate Management. An initial analysis of requirements was conducted, followed by an assessment of the resultant data components for compatibility with Turkish national Geographic Data Infrastructure (TUCBS). The proposed model enables the inclusion of land and real property data in the TUCBS, which also encompasses other land-related data themes such as buildings, land cover, topography, addresses, and administrative units. The LADM_VM is widely recognised as the primary standard for data management schemas in Real Estate Management. Therefore, the model has been developed as a sub-scheme of the LADM_VM standard for real estate management, specifically adapted to the Türkiye country profile.

In Türkiye, the national SDI initiative, Turkish National GIS (TUCBS), was launched as part of the e-government strategy to foster data interoperability across various administrative levels by establishing data production and sharing standards. TUCBS, aligning with INSPIRE in Europe, utilises the Unified Modelling Language (UML) of model-driven architecture for geographic data modelling with ISO/TC211 standards (Aydinoglu, 2016).
The main model structure of the Real Estate Management (abbreviated as TY) conceptual data model design is structured on LADM Valuation information (LADM_VM) components aligned with the TUCBS data themes. The model fulfils all requirements for land valuation as an extension of TUCBS data themes. The conceptual data models of the proposed model were designed using the basic schemas of ISO/TC211's 19xxx series standards, as well as internationally recognised and applicable technical specification rules such as data encoding, transformation, and service standards of the OGC (GD-GIS, 2019).

2.1 Overview of the Application Schema in Comparison with LADM_VM

In accordance with the structure of the ISO 19152-4 LADM_VM standard, the TY data model was developed with the following eight fundamental feature classes as *TY_TasinmazDegerleme, TY_TopluDegerleme, TY_DegerlemeUnit, TY_DegerlemeUnitGroup, TY_SatisIstatistikleri, TY_IndependentBolum, TY_Building*, and *TY_Parcel* (Fig. 1). The TY model is specifically intended to align with the characteristics of Türkiye and may be regarded as an additional model that is compatible with TUCBS and LADM models. It encompasses all the necessary classes and relationships for real estate management systems in a unified framework. Since the designed TY model was built on the LADM_VM, it maintained its relationship with the LADM Core Model. In addition, it has been defined as directly and indirectly related to several TUCBS data themes. Indirectly related data themes include *Address, Land Use, Public Administration Zones and Protection Zones*. Directly related data themes are *Building (TUCBS_BI)* and *Cadastre (TUCBS_KP*) themes.
TY_TasinmazDegerleme (TY_Valuation) class serves as the fundamental class in the TY data model, similar to the VM_Valuation in the LADM_VM model, for representing valuation information. *TY_TasinmazValuation* is defined as a subclass of the *TK_ParselDeger (Parcel Value)* feature class of the *Cadastre* theme in relation to the TUCBS model. *TY_TasinmazDegerleme* contains attributes such as appraised value (deger), purpose of valuation (degerlemeAmaci), valuation report identifier (degerlemeRaporID), date of valuation (degerlemeTarihi), valuation approach (degerlemeYontemi), type of value (degerTuru), transaction price for the valuation (islemFiyatBilgisi), objection status (itirazDurumu) and valuation identifier (tyDegerleme) (Fig. 2). Data regarding mass valuation is defined with the *TY_TopluDegerleme (TY_MassValuation)* class. It is designated as a subclass of the *TY_TasinmazValuation* class. It contains the attributes mathematical model (matematikModel), statistical analysis method (analizTuru), performance indicators (topluDegerlemePerformansi), and predicted value (predictValue).
TY_DegerlemeBirimi (TY_ValuationUnit) feature class refers to the basic transaction/record units that are subject to valuation. The value unit subject to real estate valuation can be parcel (*TY_Parsel*), building (*TY_Bina*) or condominium unit (*TY_BagimsizBolum*). It is defined with the attributes of infrastructure status (altyapiTesisatOzellikleri), the municipality to which the relevant unit is affiliated (bagliOlunanBelediye) and the type of neighborhood

(mahalleTuru), the type of the appraisal unit (turu) and the appraisal unit identifier (tyDegerBirimID). *TY_DegerlemeBirimi* is defined in relation to the LADM's Basic Administrative Unit (LA_BAUnit) class. In this way, the relationship between valuation units and cadastral/zoning plans is established with basic administrative units such as parcels, buildings, and condominium units.

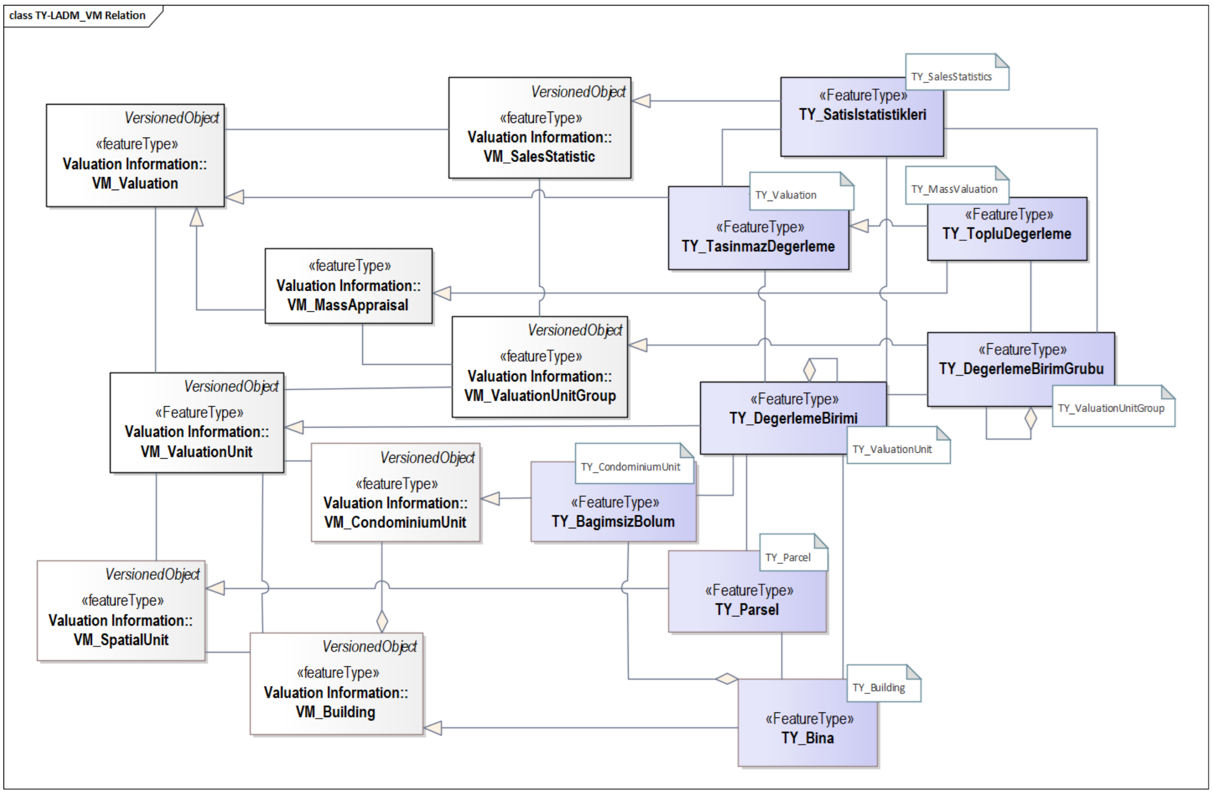

Fig. 1. The relation between TY and LADM_VM Models

Information regarding the valuation unit group subject to real estate valuation is defined with the *TY_DegerlemeBirimGrubu (TY_ValuationUnitGroup)* class. It enables the categorisation of valuation objects in terms of administrative units, use types of real estate or value regions. This class has been specifically designed to represent groups formed for the purpose of evaluating clusters by linking it with LADM's spatial unit group (LA_SpatialUnitGroup) class. It contains the attributes as the valuation unit group name (degerlemeGrupIsmi), group type (grupTuru), and unit group identification (tyDegerBirimGrupID).

TY_Parsel (TY_Parcel) refers to the parcels that are subject to valuation/appraisal. *TY_Parsel* is defined as a subclass of the TUCBS TK_Parsel (TK_Parcel) feature class and is associated with the spatial unit (LA_SpatialUnit) class of LADM. It involves the geometric information and includes the legal information in the cadastral systems related to the parcel. The TK_Parsel class has links with the TK_Tescil (TK_Registration) and HaklarKisitlamalarSorumluluklar (RightsRestrictionsResponsibilities) classes, enabling the execution of essential queries and analyses on cadastral data. These relations enable the recording of changes caused by technical applications on parcels, the registration of spatial easement rights, the management of spatial and legal limits on the parcel, and the integrated evaluation of cadastral/zoning plans. It is crucial to establish these relationships and consolidate the pertinent information in one place for comprehensive real estate management. It is defined with the location of the parcel within the cadastral block (adaIciKonum), current usage information (guncelKullanimTipi), floor area ratio (kaks), ownership information (mulkiyetDurumu), the width of the road facing the front façade of the parcel (onCepheninBaktigiYolGenisligi), and length of the front façade of the parcel (onCepheUzunlugu), parcel area (parselAlani), planned use in the zoning plans (planlananKullanimTipi), building coverage ratio (taks), parcel identifier (tyParselID), the construction order of the parcel determined in the zoning plans (yapiNizami), number of fronts facing the road of the parcel (yolaBakanCepheSayisi), ground condition (zeminDurumu) and slope (zeminEgimi) of the land on which the parcel is located attributes (Fig. 2).

TY_Bina (TY_Building) represents the buildings subject to appraisal. By integrating the architectural structures along with their geometric data, the management of building information may be conducted with a focus on its value. TY_Bina is defined as a subclass of TUCBS Building and LADM_VM building (VM_Building) feature classes and is associated with LADM's spatial unit (LA_SpatialUnit) class, as in the TY_Parsel class (Fig. A.1 and A.2). This class includes area (alan), number of residences (bagimsizBolumSayisi), equipment elements and types of the building (binaDonatiUnsurlari), energy performance (binaEnerjiPerformansi), infrastructure installation of the building (binaTesisati), facade material (disCepheMateryali), volume (hacim), heating source (isitmaKaynagi), heating system (isitmaSistemi), type of use (kullanimTuru), building identifier (tyBinaID), construction quality (yapimKalitesi), building material (yapimMalzemesi), construction date (yapimTarihi), number of floors below ground (zeminAltiKatSayisi) and above ground (zeminUstuKatSayisi) ground attributes.

TY_BagimsizBolum (TY_CondominiumUnit) is an individual unit that is subject to the valuation process and is categorised as a type of valuation unit. This class defines as a subclass of TUCBS Building - Condominium Unit and LADM_VM's VM_CondominiumUnit feature classes, as in TY_Bina, and it is also related to LADM's LA_LegalSpaceBuildingUnit class. It contains attributes as; land share of the independent section (arsaPayi), gross unit area (bagimsizBolumBrutAlani), net unit area (bagimsizBolumNetAlani), type (bagimsizBolumTuru), the floor on which the unit is located (bulunduguKat) and its floor type (bulunduguKatTipi), existing add-on/accessory information (eklenti), usage type of the condominium unit (kullanimTuru), ownership status (mulkiyetDurumu) and individual partition identifier (tyBbolumID).

TY_SatisIstatistikleri (TY_SalesStatistics) provides information on sales statistics derived from real estate transaction prices. This class is developed in collaboration with TY_TasinmazDegerleme, TY_DegerlemeBirimi, and TY_DegerlemeBirimGrubu to provide a comprehensive overview of the registers that contain sales prices and statistics (Fig. 2). It has attributes as; the density of purchases and sales for the relevant real estate valuation unit/unit group (alimSatimYogunlugu), the date of statistical analysis of sales (analizTarihi), mortgaged (anaTasinmazIpotekliSatis) and general real estate sales (anaTasinmazSatis), mortgaged (bagimsizBolumIpotekliSatis) and general independent section sales (bagimsizBolumSatis), price index (fiyatEndeksi) and index calculation date (fiyatEndeksiTarihi), average price per square meter (m2BasiOrtalamaFiyat), base price index (tabanFiyatEndeksi) and index calculation date (tabanFiyatEndeksiTarihi) and sales statistics identifier (tySatisID).The data in the TY_SatisIstatistikleri class is derived from the data recorded for the specific valuation unit within the valuation class, indicating a relationship between these classes. Value maps can be generated using the data stored in the TY_SatisIstatistikleri class.

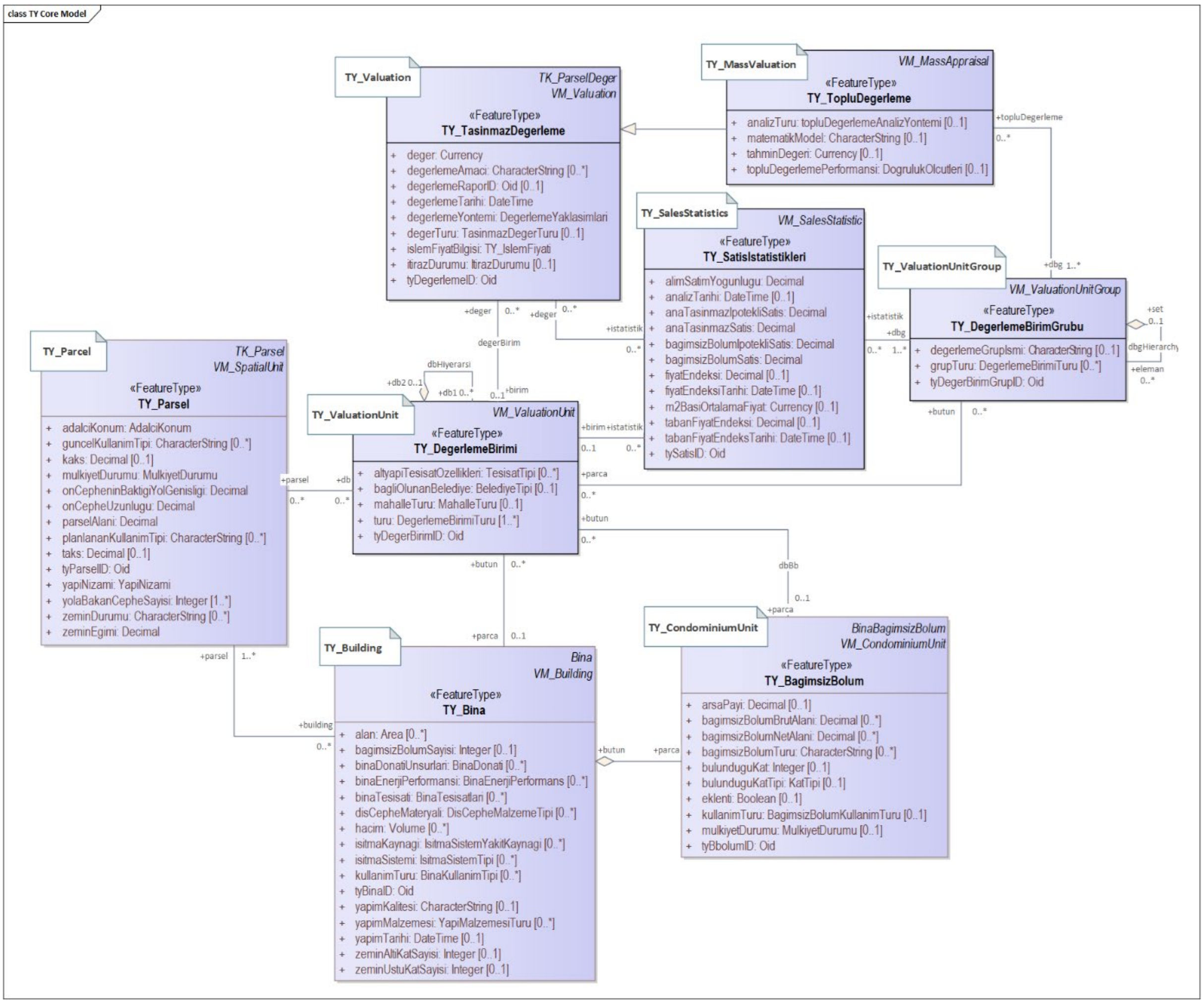

Fig. 2. Detailed core mode of TY

External factors, such as the view, proximity to points of interest (POI), noise levels, and amount of sunshine, are significant considerations in the valuation of real estate. The features derived from geographical analysis can be efficiently computed by documenting the parameters utilised in valuation databases that are integrated with 3D cadastral databases. This profile also incorporates features derived from geographical analyses using 2D and 3D datasets (Fig. 3). The *TY_DegerlemeBirimi3B (TY_ValuationUnit3D)*, *TY_BagimsizBolum3B (TY_CondominiumUnit3D),* and *TY_Kat (TY_Floor)* feature classes in the 3D profile were designed to facilitate data sharing in the construction and facility management industries, aligning with the TUCBS and INSPIRE Building data themes, CityGML, and buildingSMART - ISO 16739-1: Industry Foundation Classes (IFC) standards.

The *TY_DegerlemeBirimi3B* was defined as a subclass of the *TY_DegerlemeUnit* with GM_Object geometry. The 3D geometry allows for the precise definition of parcel, building, and building independent section geometries. In this way, the model design incorporates attributes for urban *functions* (KentFonksiyonOzellikleri) and socio-economic features (mahalliOzellikler) that can be calculated using 3D GIS analysis within the *TY_DegerlemeBirimi* (Fig. 3). *TY_BagimsizBolum3B* is classified as a subclass of the *TY_BagimsizBolum* in compliance with the 3D profile of the TUCBS Building data theme. It is also defined in relation to *TY_Kat (TY_Floor)* which consists of independent sections that are not defined according to the building structure but can also be defined according to logical evaluations (Fig. 3). *TY_BagimsizBolum* class were defined with the attributes that can be calculated/modelled with 3D GIS analysis and modelling of the independent section as the facade direction (bagimsizBolumCepheYonu), number of bathrooms (banyoSayisi), add-ons (eklenti) and their types (eklentiTuru), solar potential (gunesPotansiyeli), exposure to noise (gurultuDurumu), calculated gross (hesaplananBrutAlan) and net (hesaplananNetAlan) area, view status (manzaraDurumu), number of rooms (odaSayisi), kitchen (mutfakSayisi) and toilet (tuvaletSayisi). The *TY_Kat* feature class is a crucial component of 3D Building Information Models (BIM). It contains information such as the number of independent sections (bagimsizBolumSayisi), floor usage type (katKullanimTipi), floor number (katNumarasi), floor ceiling (katTavanYuksekligi) and floor height (katZeminYuksekligi), floor type (katTipi) attributes (Fig. 3).

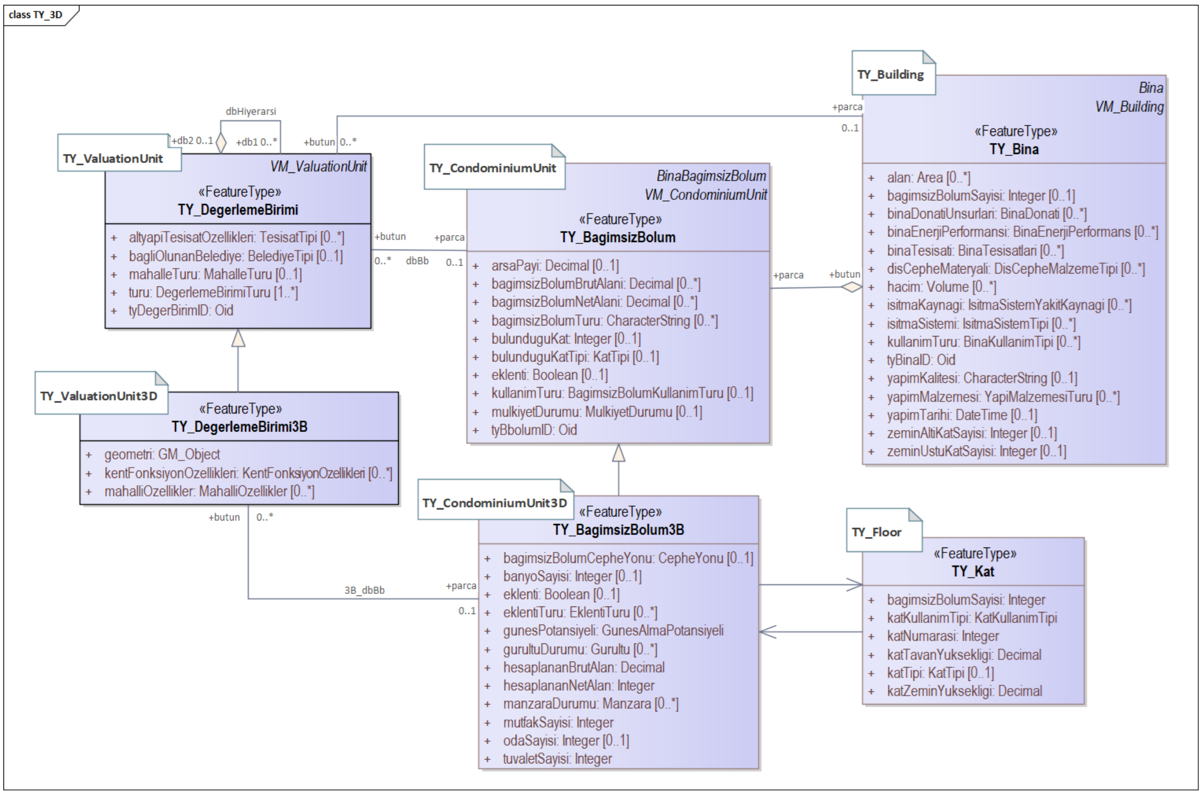

Fig. 3. 3D profile of TY data model

3. CASE STUDY

Within the scope of this study, 2D/3D factors affecting real estate value were defined in five thematic categories, taking into account international standards, literature reviews and existing 3D data model content (Biljecki et al., 2015; El Yamani et al., 2023, IAAO, 2017; IVSC, 2022; Jafary et al., 2022; Kara et al., 2023, 2021; Radulović et al., 2023; RICS, 2017; Sisman and Aydinoglu, 2022; TEGOVA, 2020; TKGM, 2024; Yalpir et al., 2021). Data regarding the factors in the Socio-Demographic Characteristics, Planning Characteristics, Urban Functions categories are generally related to traditional cadastral systems and are represented by 2D geometry. On the other hand, with the developing geographic information technologies, 3D building and condominium unit models at different levels of detail have begun to be produced. By GIS-integrated management of the 3D models produced, datasets related to the 3D factors defined in the building and condominium unit factor categories, as well as the 2D factors affecting the real estate value, may be obtained. In this context, a summary table of these factors that have the potential to affect real estate value.

Study area was determined in Amasya-Merkez district, where the first pilot 3D building models were produced within the scope of the "3D City Models and Cadastre Project" initiated by the General Directorate of Land Registry and Cadastre (GDLRC) in Türkiye (GDLRC, 2024). Relevant datasets were used to produce nominal value scores in the study area. The datasets include related factors were obtained from the Turkish Statistical Institute (TurkStat), the GDLRC-Parcel Query Application and Amasya Municipality city plans, the Disaster and Emergency Management Presidency (AFAD), Amasya Municipality, and Open Street Map (OSM), and GDLRC's 3D City Models and Cadastre Project.

To create parametric value scores for real estate valuation, it is necessary to calculate the weight coefficients representing the importance level of the factors affecting the real estate value (Sisman et al., 2023). Multi-Criteria Decision Analysis (MCDA) methods are effectively utilized to determine the weights of the criteria in decision problems that involve many factors such as real estate valuation. Thus, Best Worst Method (BWM) was used in this study.

In this study, the questionnaires were conducted directly with appraisers working in the public and private sectors and academicians conducting research on real estate appraisal issues. Experts were surveyed and each of the questionnaires was evaluated with BWM. The weights for the calculated factor groups and sub-factors were given in Table 1.

Table 1. Determining the factor weights affecting real estate value

Factor Group	***Factors With Weights***
Socio-demographic characteristics (0.214)	***Population (0.058)*** *(population density, women living in the neighbourhood (%), men living in the neighbourhood (%), children (0-14 age) living in the neighbourhood (%), young (15-24 age) living in the neighbourhood (%), adults (25-65 age) living in the neighbourhood (%), old (65+ age) (%) living in the neighbourhood),* ***Education Level (0.059)*** *(illiterate people (%), uneducated people who can read (%), primary school graduates (%), secondary school graduates (%), high school graduates (%), university graduates (%)),* ***Income Level (0.063)*** *(Number of people with group A+, A, B, C, D, size of income, income per capita),* ***Spending (0.034)*** *(food expenditures, healthcare expenditures, transportation expenditures, education expenditures, sheltering etc.)*

Planning Characteristics (0.163)	***Zoning Characteristics (0.065)*** *(building coverage ratio, floor area ratio**,** parcel area, building order form (detached building, attached building), permitted parcel usage type),* ***Parcel Physical Characteristics (0.046)*** *(number of facades facing the road, facade front length, front facade road width, location of parcel in building block, land slope, ground conditions),* ***Property Status (0.052)*** *(condominium, condominium easement, timeshare)*
Urban Functions (0.216)	***Education Facilities (0.041)*** *(kindergarten, primary and secondary school, high school, university),* ***Healthcare Facilities (0.041)*** *(local healthcare facility, hospital, pharmacy, emergency health service station),* ***Transportation (0.063)*** ***(****Rail System Stations, Airport, Sea Transport Stations, Road Transport Station, Proximity to Roads),* ***Points of Interest (0.027)*** *(bazar centre, shopping mall, district bazaar, market, cultural facility, coast, green area, sport facility, restaurant),* ***Public Services (0.020)*** *(administrative facility, courthouse, post office, bank, fire station, security unit),* ***Industrial Facilities (0.008)****, (petrol station, industrial facility, treatment facility),* ***Religious Facilities (0.016)*** *(worship, cemetery)*
Building Characteristics (0.209)	***Building Physical Characteristics (0.127)*** *(age of building, number of total building floors, heating system, existence of heat insulation),* ***Building Installations (0.082)*** *(within housing estate, existence of car parking, existence of pool, existence of elevator, existence of children playground)*
Condominium Unit Characteristics (0.196)	***Condominium Unit Physical Characteristics (0.110)*** *(landscape, direction, floor level)****, Condominium Unit Interior Characteristics (0.086)*** *(floor area, number of rooms, room type, number of balcony, number of bathroom)*

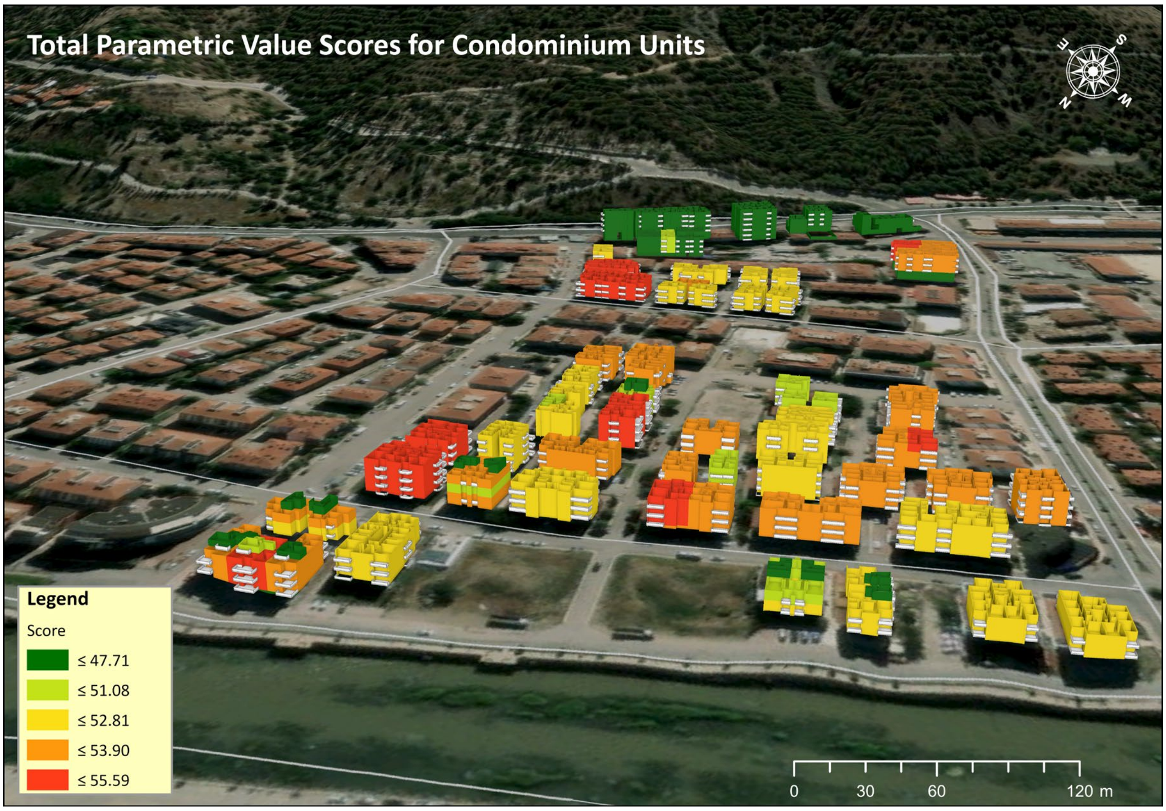

Fig. 4. Total parametric value scores for condominium units

The calculation of the parametric value scores was carried out in a hierarchical structure and a process was followed from the neighbourhood level to the condominium unit level. Geographic data representing the 2D/3D factors defined in Table 1 were analysed in the GIS environment to produce parametric value scores in real estate valuation. Finally, the scores calculated for the five groups were combined and parametric value scores were calculated at the condominium unit level, as shown in Fig. 4.

4. CONCLUSION

While traditional cadastral systems provide legal information about properties with 2D geometric information, 3D building and dwelling models can provide more meaningful data for GIS analysis that can be used to increase the accuracy of real estate valuations. If a country has an effective National Spatial Data Infrastructure (SDI) with 3D support, it can be used to link different data themes, such as buildings, cadastre, land use, addresses, etc., that are required in valuation processes. An extension to NSDI may be required to meet 3D real estate valuation needs. As the ISO 19152 Land Administration Domain Model (LADM) is the standard that considers links between cadastral, building, land use and property valuation registers.

After developing an extension valuation model of Turkey National GIS, compatible with LADM, A case study was conducted in a city, where Türkiye's first 3D building and condominium unit models were produced. Following the calculation of the weights, geographical analyses were performed, and the results were standardised. The developed real estate valuation model, which is structured as a part of NSDI, namely TUCBS, is evaluated with the data collected from the questionnaire. Parametric score values for each real estate are calculated based on the results of the questionnaire for five different group and one aggregated value. The aggregated score value, which can be considered as an approximation of the market value of real estate, is calculated by aggregating the score values of each group. Since it is not possible to obtain real estate values in the area where the case study was conducted, this approach is followed in testing the model. As a future work, it is planned to test the developed model with real data in another case study area. Furthermore, the relationships between indices generated in smart city applications (e.g., quality of life) and real estate values need to be investigated, which is specified as future work.

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