3D VIRTUAL REALITY MODEL FOR MULTI-STORIES BUILDING AND UTILITIES WITH DIFFERENT VERTICAL OWNERSHIP ID's

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ABSTRACT: The current scenario of house ownership registration in Adama Municipality, Ethiopia depends either on hard copy or 2D designs of CAD and GIS. This approach of ownership in apartments creates confusion when a single coordinate is linked with different vertical parcel ID's. 3D property registration has become a vital need to reveal all obscure illustrations of the multi-stories buildings optimally. For facility management, it is essential to have a detailed and updated database of underground and surface utilities. Nevertheless, such data are not always available with adequate accuracy, and 2D fails to give information regarding the vertical profile of underground utilities. This may lead to misconception for field workers and specialist as well. The building footprints of condominiums were extracted from hard copy data to GIS *via* CAD files and aerial photographs. Later, cadastral information's with socio-economic data, legal documents and architectural plans were collected and integrated into the GIS environment. Moreover, the footprints of each floor having the same geographic coordinates with different Mean Sea Level (MSL) were measured through the total station and extruded to its dimension. Interestingly, to register and visualize the complex reality in 3D, Computer Generated Architecture (CGA) code was employed to design 3D urban environments by transforming 2D GIS Data (building footprint) into smart 3D city models using city engine. The virtual reality was incorporated into the condominiums through real textures, roofs, staircases and utilities as a source from close-range photogrammetry. The resulted from the web-based virtual 3D model was validated topologically and ensured the actual appearance of the building and vertical ownerships of multi-stories having the same geographical location. Finally, in this study, a prototype has been developed for mapping underground utilities using GIS, Trimble Sketchup and VBA macro to integrate attributes for 3D texturized features. The dimensions, locations and vertical profile of the features (utilities) were collected using the total station. This new approach, especially for underground infrastructure using 3D GIS techniques, is efficient and cost-effective to integrate and update existing traditional CAD maps.

1. INTRODUCTION

Modernist urban environments are characterized by their architectural complexity and the versatile uses of space in which a spectrum of distinct Rights, Restrictions and Responsibilities (RRR) converge with the similar land parcels. This choice of RRR's requires proper 3D registrations complying with each legal structure, as well as systematic encoding and modelling, fully exploiting technical capabilities of 3D representations (Tsiliakou, 2003). The population is significantly increasing in Ethiopia, which results in a considerable number of land allocating for housing and development activities.

To secure this, the government of the federal democratic republic of Ethiopia design to develop town vertically as much as the capacity of the city permitted. Due to this policy, condominium houses or buildings are constructing throughout the cities of the country.

Most condominium houses in Ethiopia are still faced with several challenges that include inadequate official property records with necessary technological supports. The experiment in the registration of intersecting and interconnecting buildings above and below the surface in cadastral mapping on 2D parcels is quite challenging (Stoter, 2004). Lack of instrumental technology inland delivery leads to increases case of corruption, bribery and favouritism by the town and city officials. According to the Addis Ababa housing development agency census, two houses from each condominium distributed wrongly (Bedada, 2015)

Hence there is a need for condominium community patterns of interaction that may be influenced by hierarchies concerning the owner's association (Zelalem, 2012). The same trend in other cities which have condominium houses requires a designed and protective technological mechanism that can register for their 3D properties. Although its surface boundary will be intended to delineate in 2D cadaster where the condominium building situated, still the Ethiopian condominium houses are text registered its 3D property units. Only utilizing a cadastral system in which ownership rights are accurately designed and guaranteed can prosperity be achieved (Ayazli, 2008). In case of a building is divided into several apartments, and they belong to different owners adding 3D dimension is necessary (Stoter, 2003).

The advances in Geospatial Technology the 3D modelling and visualization of buildings and utilities has attracted the attention of urban planners. Therefore, many new solutions are being developed to these processes faster and cheaper. The reason for their growing popularity is due to an increase in the utilization of spaces in the 3D city models. They can be applied besides not only for research and education purposes in urban planning, archaeology, architecture, engineering but also for virtual reality in the movie and gaming industries (Parish, 2001). One of the best methods to create a 3D city model in a short time and with low expenses is procedural modelling (Watson, 2008). But other methods for modelling the buildings and utilities manually give an overview of the process of 3D modelling which includes 3D data acquisition, modelling and rendering steps, including the collection of texture by close-range photogrammetry (Luan, 2008). Many observers credit IBM system with the first accurate network model usable for tracing underground utilities such as electric circuits, gas, and water networks etc. and for allowing performance analysis of network models (Antenucci, 1991).

To achieve an adequately accurate and complete representation of the subsurface features, a dedicated and extensive survey is required. Field surveying of specific surface features is accomplished with traditional topographic methods or by GPS positioning. Mapping the positions of the surface elements of networks like maintenance holes, catch basins, transformers, hydrants, exchange boxes, electric poles etc. are accurate and subsequently inferring the presence and the approximate planar location of the buried lines. Another possibility is the GPR (Ground Penetrating Radar) technique (Metie, 2007) which allows reconstructing the primary 3D geometry of underground elements with high accuracy and their vertical profile.

2. OBJECTIVES

The objectives of the study are:

- To build 2D geodatabase incorporating building footprints and socio-economic data.
- To generate a 3D model for underground and surface utilities.
- To vertically extrude and 3D modelling.
- To include the texture and utilities employing close-range photogrammetry and its validation with the real world.

3. DATA AND METHODOLOGY

Two different sets of data and methodology are employed in this study one for designing surface and another for subsurface features. The data and their sources used to generate a cadastral model, and cadastral registration systems of multilayer condominium buildings in Adama city are shown in table 1, and workflow adopted in the study (Figure. 1).

Table 1. Data and their purposes used to generate a 3D model of multilayer condominium buildings

Layers (data)	Scale	Purpose of the layer
Aerial photo	15 cm*15 cm	Building footprints and validation of results
AutoCAD	1:50 and 1.100	
Total station readings	1:1	To assign extrusion, elevation from MSL and validation of results
Socio-economic	Questionnaire	To develop the description rights, restriction and responsibility
Close range photogrammetry	3.264cm*1.8cm	To develop the texture and physical appearance of buildings

The data and their sources used to generate 3D model table 2 and workflow adopted for study for underground and surface utilities (Figure. 2).

Table 2. Data and their purposes used to generate a 3D model of utilities and underground features.

Layers (data)	Scale	Purpose of the layer
Aerial photo	15cm*15cm	Building footprints and validation of results
Total station readings	1:1	To assign extrusion, elevation from MSL and validation of results
Ground Penetration RADAR	1:1	To identify the locations and network pattern of underground utilities
DGPS		To identify the coordinates of surface utilities and features
Close range photogrammetry	3.264cm* 1.8cm	To develop the texture and physical appearance of buildings

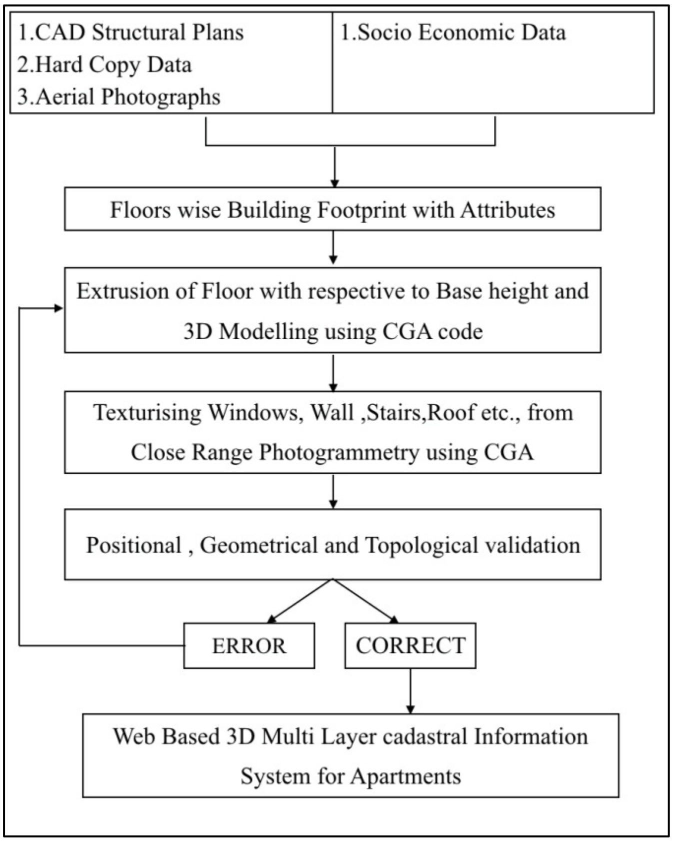

Figure 1. Workflow for 3D modelling

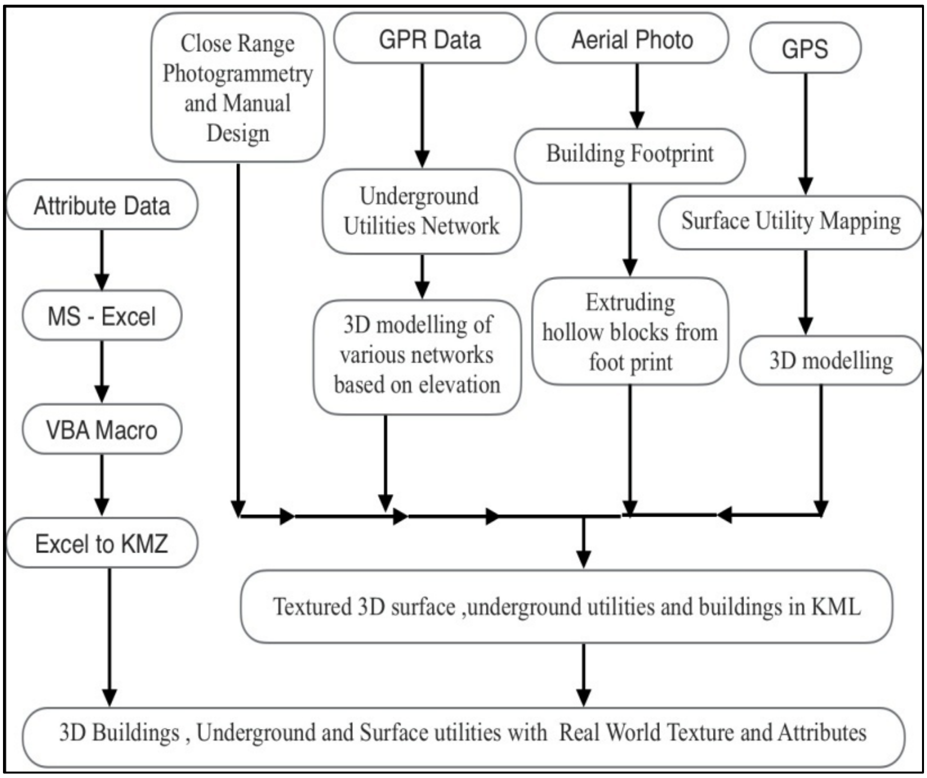

Figure 2. Methodology for underground & surface utilities 3D mapping

4. RESULTS AND DISCUSSION

The results are discussed as per the flow of objectives:

4.1 Extraction of Building Footprints

The 3D description of a 3D cadastral physical object initially starts with parcel boundaries in 2D. Parcel boundaries were extracted from the aerial photos and CAD structural floor plans (Figure 3a). The socio-economic data of different vertical parcels was attributed in GIS (Figure 3b).

Figure 3. CAD structural plans (a), building footprint on the aerial photo (b) and attributed socio-economic data (c).

4.2 3D Modeling of Building by CGA Code

The 2D database generated in GIS was imported into city engine environment then set off rules were developed using CGA code through which the floors, roofs and staircases were extruded from base height data collected by the total station (Figure. 4).

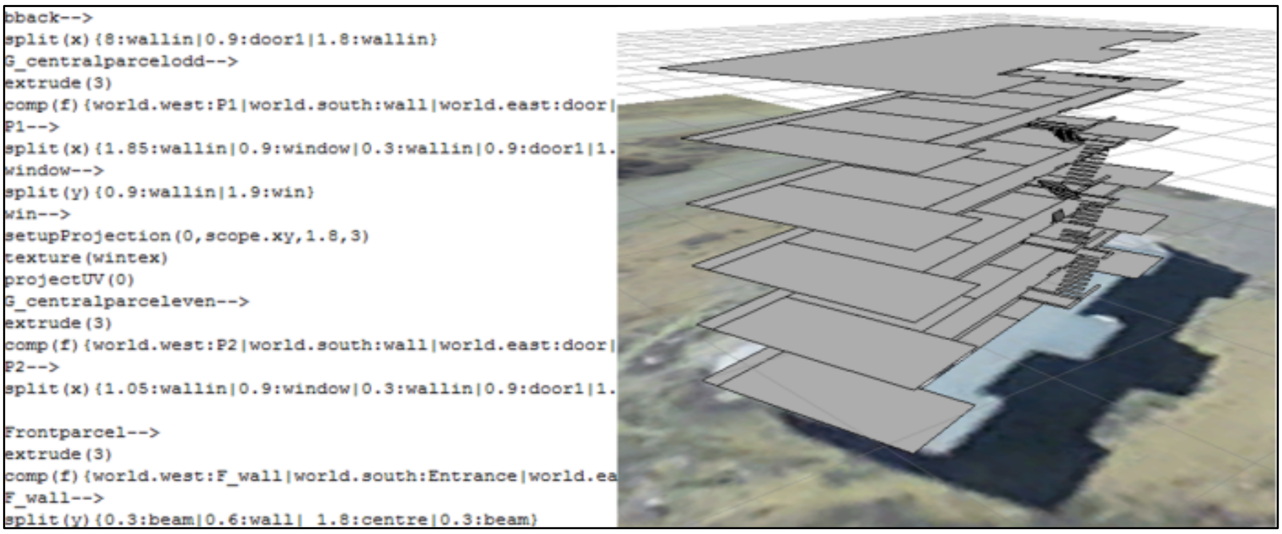

Figure 4. CGA coding for 3D structure.

4.3 Validation of Real Structures of 3D

The texture of various building features such as doors, windows, walls, stairs, roofs, warenda and handrails etc. were collected by close-range photogrammetry techniques using a high-resolution digital camera. Further, a new set of rules was included in the existing CGA code to incorporate the textures into the blocks. Finally, the generated 3D virtual model and its controls were validated topologically for positional accuracy (Figure 5a). Moreover, the CGA codes that were used to incorporate the texture as mentioned earlier (Figure 5b) of utilities were also cross-checked both for its dimension and location through hard copy plans and CAD structure drawing and resulted from features were rectified with accurate site and texture (Figure. 5c and d).

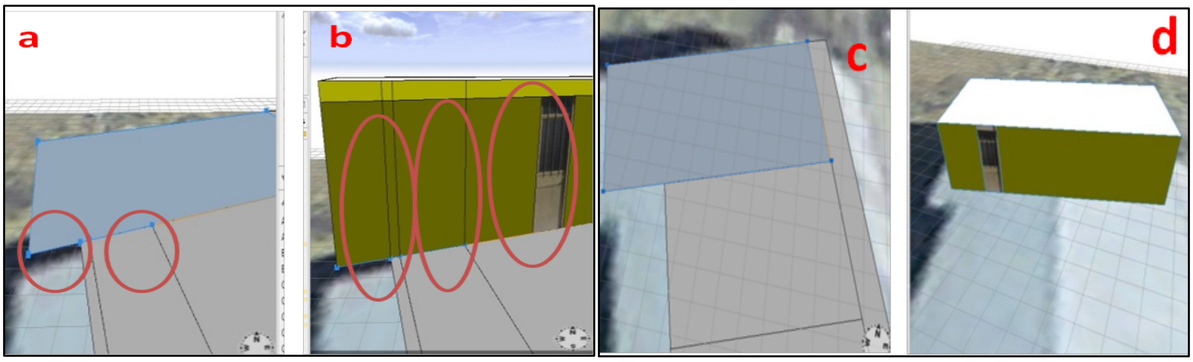

Figure 5. 2D footprint vertex error (a), (b) resulted in wrong 3D position, (c) corrected 2D vertex and (d) correct part and dimension of the door.

4.4 Extraction of Utilities Footprints and its Extrusion

The utilities from the study area were extracted using three different kinds of data as follows;

- The building footprints were extracted using high-resolution aerial photos of 15cm.
- Using DGPS the coordinates of surface utilities such as; electric lines, gate valves, tanks, street lights etc. were collected and mapped.
- The underground network pattern and along with its coordinates and vertical profile were mapped using Ground Penetration Radar.

Moreover, the surface features (Figure. 6a) were extruded from the MSL using total station data. Further, the vertical profile of the underground network was extruded by GPR (Figure 6b).

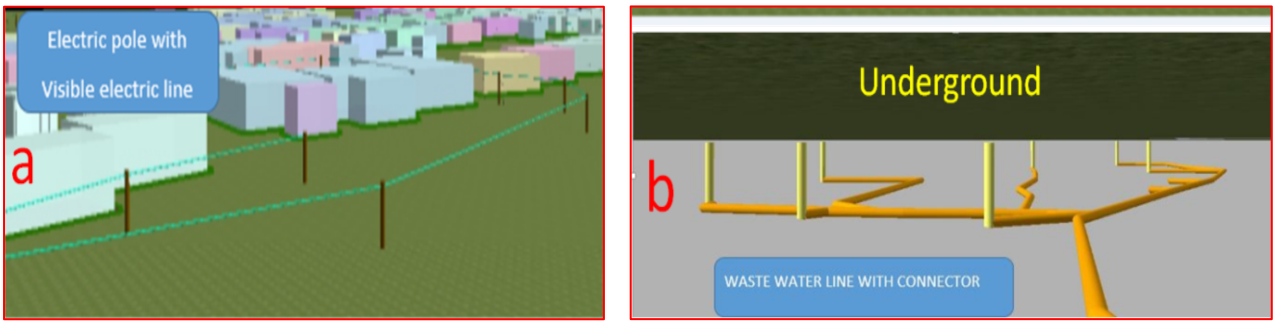

Figure 6. Extruded buildings and utilities (a), an underground network of utilities (b).

4.5 3D Modeling with real-world texture

The extruded features were representing the real world as just as hollow concrete blocks with actual-world dimension and locations. To enhance and incorporate the virtual reality effect to the surface (Figure. 7a, b) and underground utilities a fusion of software's such as Arc Scene, Trimble sketch up and Image processing through photogrammetry was carried out. Comprehensive care was taken during the design of those features which has their utility both on the surface and underground as well (Figure. 7c). The textures of some features which lays underground were designed manually (Figure. 8d).

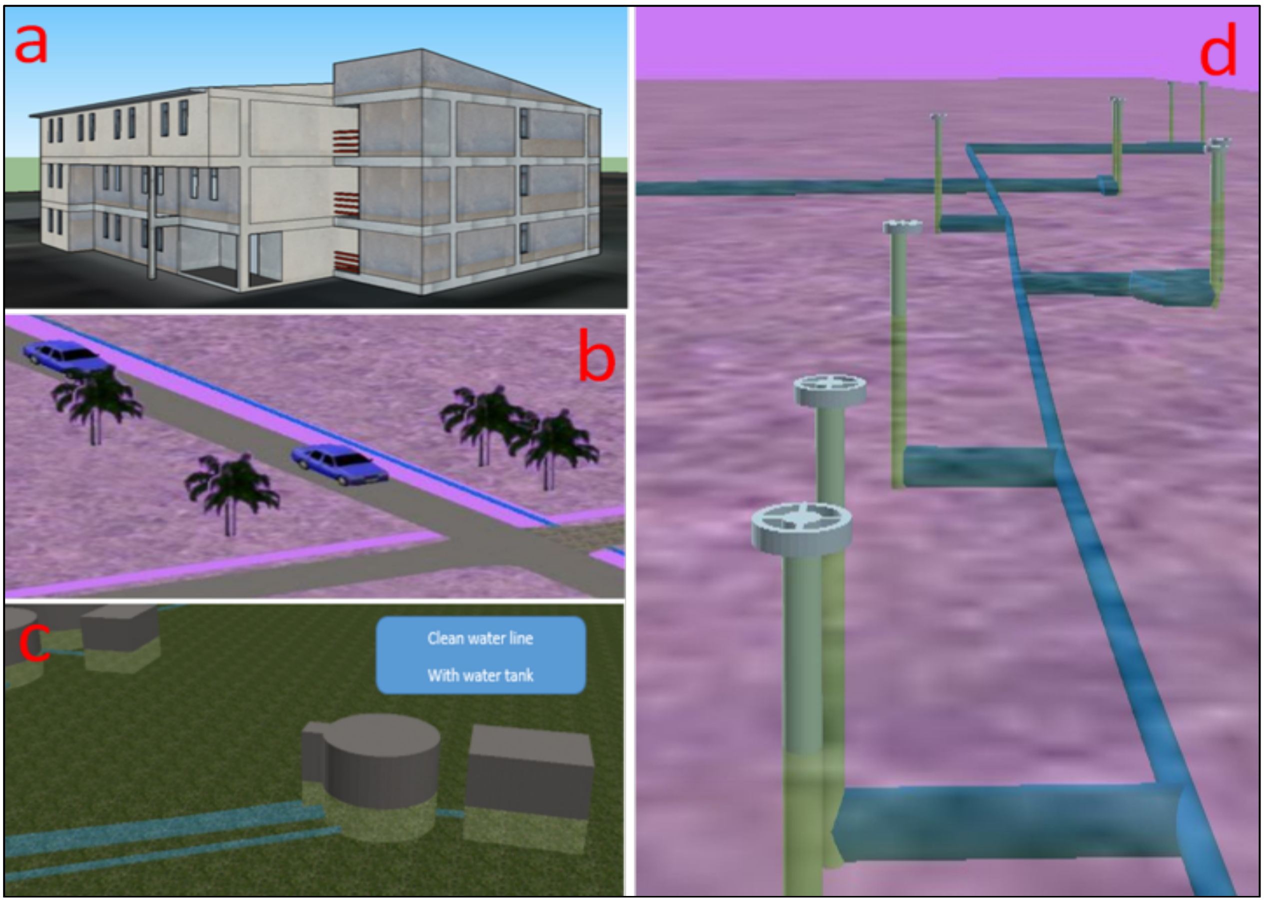

Figure 7. Virtual 3D reality model (a & b), (c) underground network linked with surface utilities (i.e. portable water tanks with its underground supply) and (d) manually textured water supply line with its gate valve.

4.6 Attribution of 3D utilities

As the Modeling was carried out using different software's, the attributes created on the GIS platform were lost during the conversion from one data type to another. Therefore, VBA macro was used to generate and convert attributes from Excel to KML file. The created KML file was linked to its ground features using latitude and longitude as the required field. The attribute was made visible by a mouse over click event (Figure. 8).

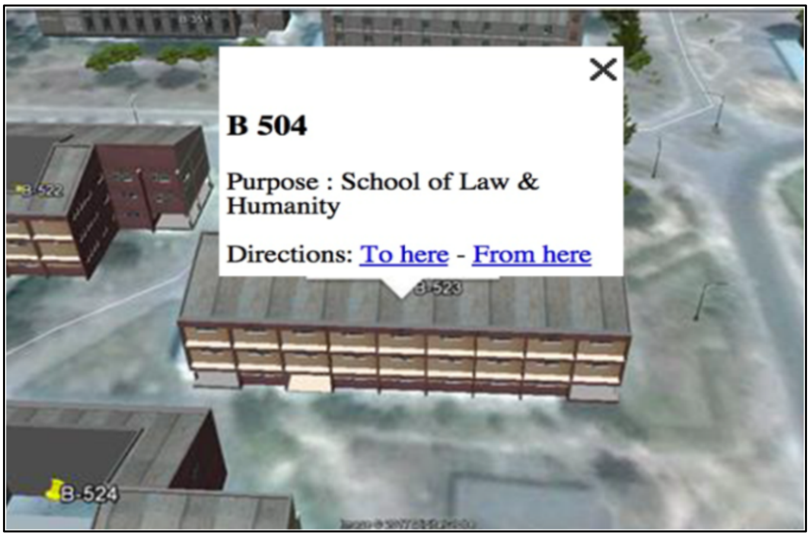

Figure 8. The attribute information of 3D building

4.7 3D display on Google earth

As the generated output can be viewed only on the software in which it has been developed. To make 3D layout software independent, the 3D features and buildings were exported to Google Earth format so that they can be viewed along with its attributes. The virtual tour is made to available both online and offline secured network (Figure 9).

Figure 9. Google earth interface of the study area.

5. CONCLUSION

In the conventional system of maintaining the database using only GIS and CAD doesn't cover the 3D aspects. Hence, there is necessary to customize the gap of techniques for multilayer 3D buildings. The study was procedural based, CGA code for transforming 2D to 3D floor wise textures (by close-range photogrammetry technique) of building footprints (Figure 10b). Moreover, the validation was carried out for position, geometry and topology for partition, orientation, texture and location in 3D (Figure 10a). In the case of blocks which were not matching with real-world (Figure 10b), the rules and algorithms were recorded. The final 3D web-based multilayer cadastral information system can be checked with query with their vertical spatial appearance of ownerships (Figure 10c). In Ethiopia, the land records are still based on conventional forms through hard copy and drawing; therefore, this new technique brings more accurate land information with their unique house owner records for vertical settlements in future. The study would be me useful to planning authorities of Ethiopia for maintaining the taxation and standing house ownerships 3D geodatabase records to minimize the disputes.

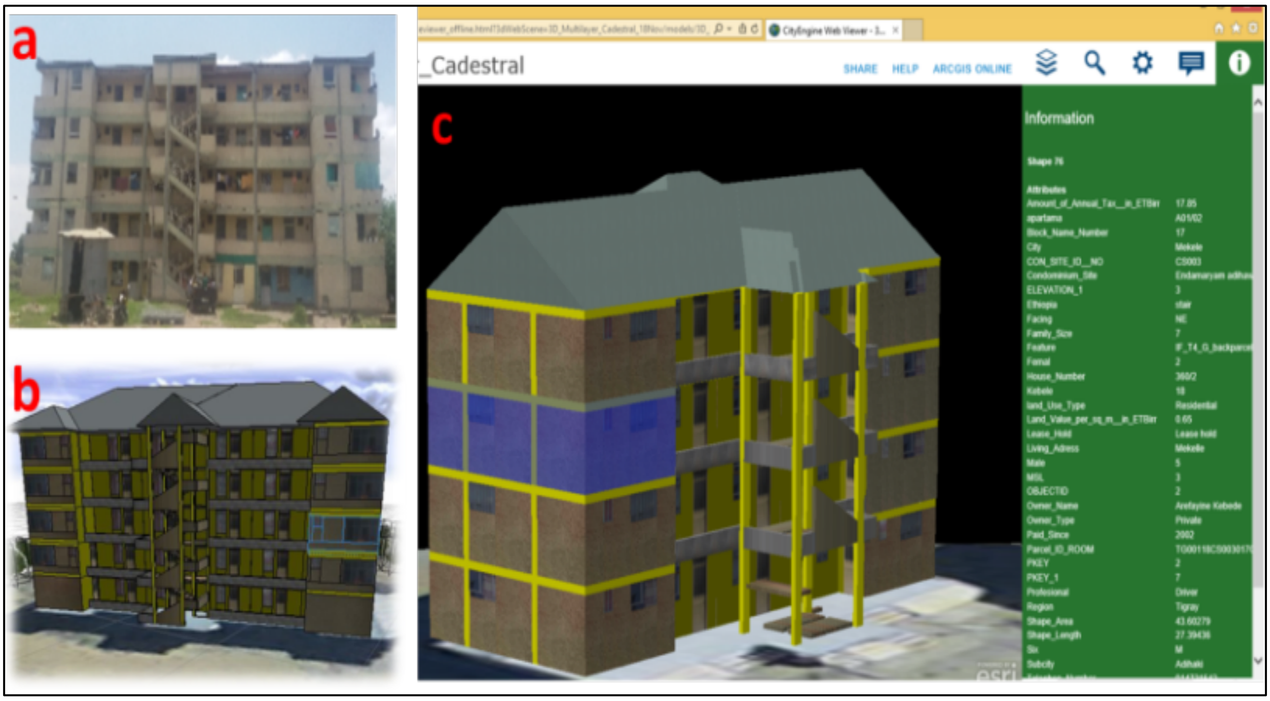

Figure 10. Texture by CRP (a), Virtual 3D (b) and (c) vertical ownership information.

3D Modeling of underground utilities and surface features enhances better visualization, understanding, maintenance and planning. Several techniques and methods are available for 3D Modeling. Each 3D modelling methods and techniques have many advantages and some limitations. Some ways are costly and not very easy to make the 3D Modeling. However, this method gives a cost-effective solution for Virtual 3D Modeling. The 3D Campus model can be published on the website of the Institute or University to attract visitors. The interface of the layout is simple and easy to use. It provides a lot of possibilities to users for mapping, planning and designing in a bird's eye view. The study area is having mix bio-diversity as well as different structural designs in constructed buildings and dense underground utility network. The virtual plan prepared with a fusion of various software's is useful to understand the underground utilities and surface features with its spatial coordinates, attributes and real-world textures. The Smart Campus concept can help provide a piece of information that enabled infrastructure for users.

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