

3D Cadastral Modeling for Registration of Sectional Rights, Tax Collection and Integration into the National Land Information Management System in Kenya

Benard ODHIAMBO, Gordon WAYUMBA, Samson AYUGI, Julia WAKABA, Japheth NYANDORO, Brian MOENGA and Evans KIPCHUMBA, Kenya

Key words: 3D Cadastre, Laser Scanning, UAV Mapping , 3D Cadastral Model

SUMMARY

This paper presents a summary of a project that was carried out in a residential area in Nairobi Kenya to provide a solution to 3D modeling for tax collection, registration of sectional properties and integration of the 3D cadastral models into the Kenyan Land Information Management System. The methods adopted included provision of geodetic control around the building with GNSS Rover and Reflectorless Total Station, Terrestrial Laser scanning of both the external and inside-building walls, and acquisition of aerial digital imagery with a UAV. The acquired data were processed and visualized through various software and libraries such as the Leica Cyclone Register 360, AutoDesk Recap, Blender, QGIS, PostGresQL, CesiumJS, ThreeJS, Python amongst others, a complete 3D model of the building in its true location on the world globe by cesiumjs, together with sectional plans, 3D Visualization, and maps and locations of all the sectional units inside the building. The authors observed that the product fulfills the original objective of the exercise and have currently been hired to carry out 3D mapping of several flats in Nairobi. The conclusion is that the tool provides a solution to many of the 3D challenges that have not been solved on the ground.

3D Cadastral Modelling for Registration of Sectional Rights, Tax Collection and Integration into the National Land Information Management System in Kenya (11289)

Benard Odhiambo, Gordon Okumu Wayumba, Japheth Nyandoro, Kipchumba Evans and Julia Wakaba (Kenya)

FIG Congress 2022

Volunteering for the future - Geospatial excellence for a better living

Warsaw, Poland, 11–15 September 2022

3D Cadastral Modeling for Registration of Sectional Right, Tax Collection and Integration into the National Land Information Management System in Kenya

Benard ODHIAMBO, Gordon WAYUMBA, Samson AYUGI, Julia WAKABA, Japheth NYANDORO, Brian MOENGA and Evans KIPCHUMBA, Kenya

1. INTRODUCTION

Pressure on land, especially in the Central Business Districts has led to overlapping of land rights and interlocking constructions. Even though the creation of the property rights to match these developments are available within the existing legislation, describing and integrating them in the cadastral registration systems poses a challenge. Currently, the challenge with 3D Cadastral properties is how to register the overlapping rights and the interlocking constructions in a typical 2D register [Stoter, 2004]. In addition, the government would like to collect taxes from the 3D vendors who have purchased rights in the flats in the 3D cadastral blocks. Unfortunately, most of these flats have not been mapped and there are no models for incorporating the ownership with the 3D spaces in the buildings. Also, the existing Architectural plans have not been integrated in the 3D Cadastre hence it is difficult to identify the vendors of the various Architectural units for taxation and other management requirements. In Kenya for example, several high-rise buildings for residential and commercial purposes have recently sprung up in different parts of the cities and the government would like to incorporate them into the recently launched National Land Information System (NLIMS) for tax collection and other management requirements. This has been a challenge as currently there are no suitable models to incorporate the 3D Cadastre into the NLIMS and even their locations are not available from the government cadastral system. In order to solve this problem, a partnership research project was conceived between the 8Teq solutions and the Technical University of Kenya, Nairobi to develop a tool for mapping and modeling 3D property rights. (i) develop a 3D cadastral model that would support the registration of sectional properties rights within the 3D buildings, (ii) support efficient tax collection from the mapped units, and (iii) assist in the integration of the 3D cadastral models into the recently launched NLIMS. The methods that were deployed in the project are presented below.

2. METHODOLOGY

Methodology involved the selection of a residential 17 floor building in Pangani Estate in Nairobi. This Housing development was initiated by H.E. the President of Kenya as part of his Legacy, popularly known as the Big Four Agenda which included; Food security, Affordable Housing, universal health care, manufacturing and Job creation. In carrying out the 3D mapping, the following approaches were deployed.

Diagram in Figure 1.1 shows the general layout of the methodology which consisted of; acquisition and digitization of the 2D cadastral plan of the site and transformation of the

3D Cadastral Modelling for Registration of Sectional Rights, Tax Collection and Integration into the National Land Information Management System in Kenya (11289)

Benard Odhiambo, Gordon Okumu Wayumba, Japheth Nyandoro, Kipchumba Evans and Julia Wakaba (Kenya)

FIG Congress 2022

Volunteering for the future - Geospatial excellence for a better living

Warsaw, Poland, 11–15 September 2022

coordinates from the Cassini -Soldner projection to the UTM (1960 Arc Datum) coordinate system. The next step involved provision of geodetic control around the building with both geodetic Rover and transfer of the coordinates into the building with a Reflectorless Total Station. The coordinates inside the building were used to coordinate targets on walls for georeferencing the building onto the ground controls. A Terrestrial Laser scanner was used to scan both the external and inside-building walls, and UAV was used to acquire aerial digital imagery of the roof.

The acquired data were processed and visualized through various software and libraries such as the Leica Cyclone Register 360, AutoDesk Recap, Blender, QGIS, PostGresQL, CesiumJS, ThreeJS, Python amongst others. a complete 3D model of the building in its true location on the world globe by cesiumjs, together with sectional plans, 3D Visualization, and maps and locations of all the sectional units inside the building. Figure 1.2 below shows the network for integrating the 3D models onto a 2D LIMS model.

of the assorted approach for this study

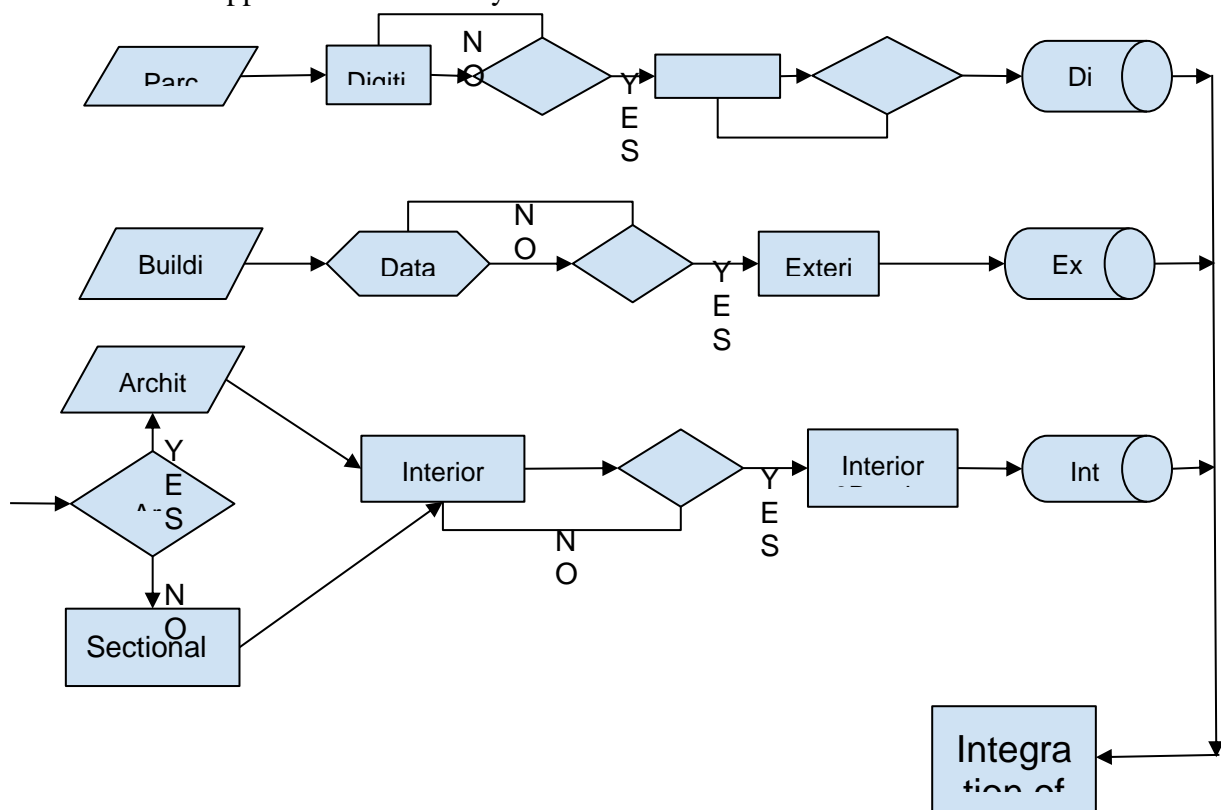


Figure 1.1: A general Flow Diagram for Methodology For 3D Modeling

Bellow is the adopted generalized UML model for the classes used:

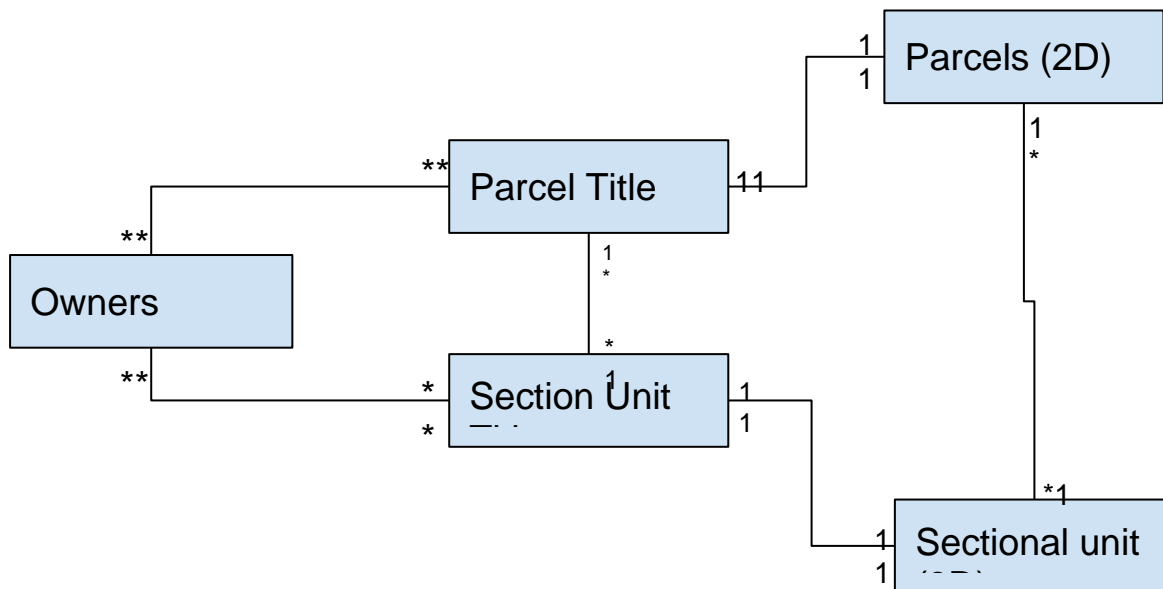


Fig. 1.2: Flow Diagram for Integration of 3D Model and the NLIMS

2.1 UAV data Capture Process

A UAV equipment was used to capture the roof data in both circular mode and parallel mode. Controls for the UAV were provided with the GNSS Rover in the UTM (1960) datum coordinate system. The UAV data captured was performed in two methods, one through double circular missions with varying radii and camera angle, and two polygon flight with camera at nadir angle as shown in a and b respectively the all process took one and half hour to complete. Collected UAV images were downloaded and loaded to drone image processing software for processing and georeferencing to produce accurate mosaic images and 3D models both point clouds and meshed models. The drone was then flown at different heights; 90+50m and 70+50 m above the ground, in order to capture the pictures of the top part of the building.

UAV data capture process involved placing of ground control target strategically within the area of study and their coordinate measured with a GNSS receiver and coordinates saved as text file to be used in the processing method in this study black circle with white dot in the center was used as the target, The uav data captured was performed in two method, one through double circular missions with varying radii and camera angle, and polygon flight with camera at nadir angle as shown in figure... ,the data capture process took less than an hour to complete.

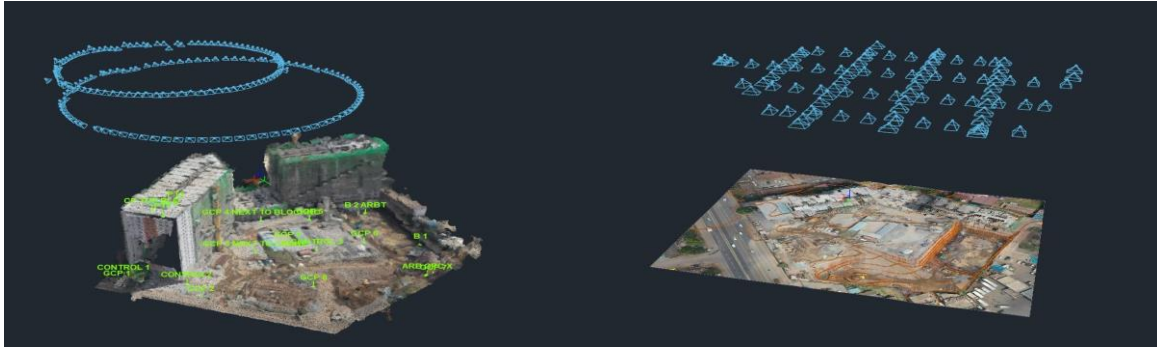


figure: left) circular drone flight paths, right) Polygon drone flight paths.



figure: left) image captured drone with camera at a cute angle, right) camera at nadir (90degree) angle

Collected UAV images were downloaded and loaded to drone image processing software for processing and georeferencing to produce accurate mosaic images and 3D models both point clouds and meshed models.

Models generated from the software were then stored ready to be used as the exterior shell of the unit models.

2.2 Lidar Scanning Process

2.2.1 Target Positioning for Georeferencing

In order to georeferenced the building onto the local UTM coordinate systems, special targets were fixed at selected points around the building and their coordinates were fixed with a Reflectorless Total Station. The placement of the target was in such a way that a single lidar scan station should be able to visualize more than one target and the best solution was found to

be when three were in site. when also scanning a single target was to be sited by at list two scan locations for better georeferencing accuracy.

2.2.2 Lidar Scanning with leica blk360

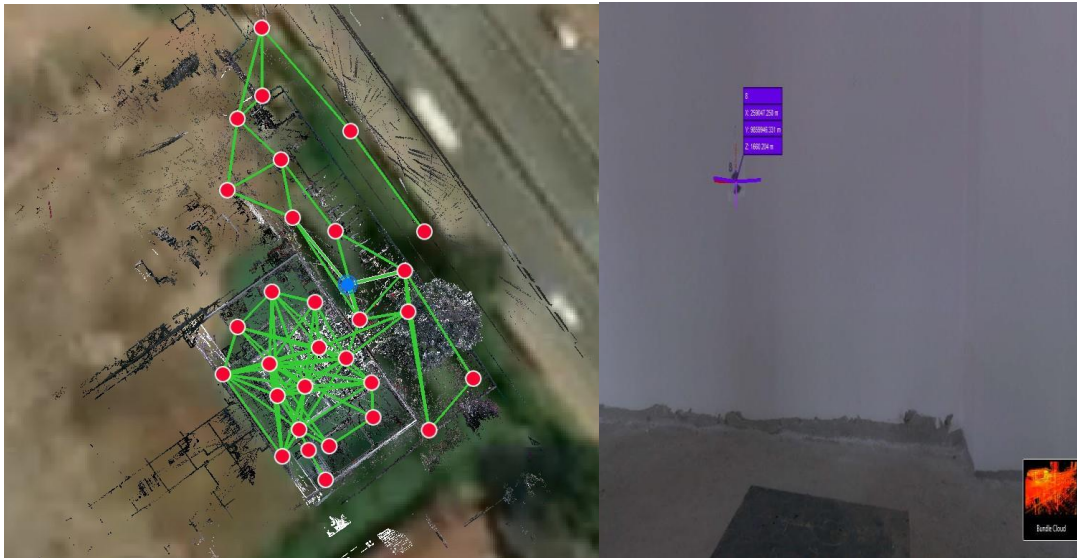
A Close Range BLK360 Laser Scanner was deployed at specific locations on the site to acquire high resolution point cloud data of the building walls from the ground floor to the seventeenth floor. Because most of the floors were similar, only selected floors were scanned and the rest were later co-registered via the stairs during the data processing (Pokswinski, S. et. al., 2021). After the scanning lidar data from the scanner were then downloaded with leica BLK datamanager into the working PC each scan data was about 300mb in file size and the all project consisted of 200 scans.



Data from the lidar scanner were then downloaded using BLK datamanager and the files loaded to Cyclone Register for Registration and Georeferencing with the target coordinates.

Registration of scan data involves the linking of individual scans to form the whole model and accuracy of the registration is provided by the software (Huang, R. et al, 2021). After all scans have been registered as shown in figure.., the control data collected from the target is applied to the scan to georeference it. The final stage on Leica Cyclone Register 360. Here, metadata such as company name, links table, targets table(histogram of errors for links displayed as a matrix of setups), sitemap image and assets are added and attached to the presentation and

published as a pdf and export the point clouds in the formats .rcp, .e57 or .pts for further cleaning on Autodesk Recap.



2.2.3 Lidar data cleaning in Autodesk Recap

The desired output of this project is the block 1 Pangani model. To obtain the building model only, the exported point clouds have to undergo some cleaning whereby unnecessary information such as trees, roads, construction workers and construction equipment to least but a few, would be removed. To perform this task of organizing and cleaning the point clouds, the software: AutoDesk Recap is used.



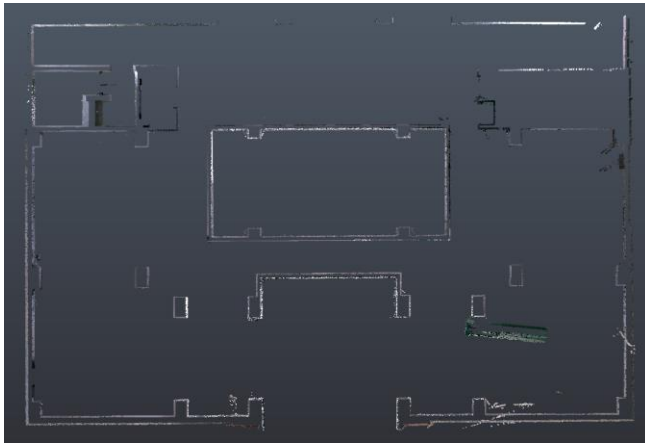
Leica BLK360 has a range of 60m and a 3D Point Accuracy of 6mm @ 10m / 8mm @ 20m. This means that for every 10m there is a 6mm error and for every 20m, there is an eight millimeter error. The buildings actual height is 55.013m high therefore the BLK360 should have been able to capture the whole building from the ground to the rooftop accurately but from the figure above, the top floors were not well captured. This is because of the 3D point accuracy

error the scanner experiences after every few meters as explained above and field distractions in the field such as trees and powerlines, that obstructed the scanner during its capturing process as seen in the figure above.

To correct and fill in the top part of the model, the pictures of the top part of the building were required and this was done by flying a UAV above the building.

2.2.4 Extraction of sectional units from Lidar point clouds.

Architectural floor plans can be generated from the lidar point clouds by Slicing using a horizontal plane the model at about 2feet from each floor whose plan is needed as shown in diagram below for the first floor in our Building. From the slides lidar point cloud digitization can then be done to trace the wall and pillars of the floor to extract the desired units, since the lidar data have all the 3D coordinates (x,y,z) the unit extracted had the same too.



2.3 Integration of all data and development of visualization web application

Using the format of the attribute data provided, an object relational database was designed with standards from the LADM (ISO 19152:2012) and 3D LADM (Van Oosterom, 2013)to store the data and enable data manipulation and querying. These data had relationships with 3d spatial units representing the sectional property units. PostgreSQL with Postgis extension was used to store the attributes and spatial unit poth as 3D geometries and gltf files. Django Python web development framework is used to interface between the database and the front-end for better

data communication through API. The data stored about the sectional unit are unit number, unit area, unit factor, sectional unit plan image, parce of the sectional unit Folio Registry Number.



The front-end web application was developed with Angular framework with cesium js library and leaflet library. cesium js is a geospatial web 3d visualization library which provides capabilities of visualizing 3d spatial data in an interactive manner as shown in the above figures. The globe imagery provided by cesium js was used as the base layer for the visualization together with the captured and processed orthomosaic from drone nadir imagery. The web visualization provides the users with capabilities of turning the unit exterior cover off and on, and also give detailed information about each unit when clicked by the user.

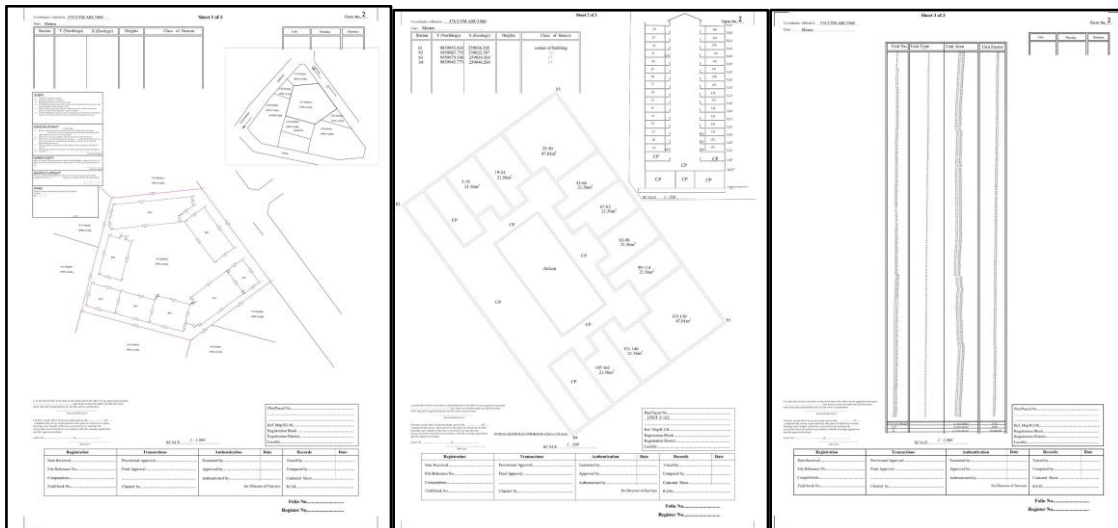
3. RESULTS

This is a 3D visualization of the individual units in the building stacked on top of each other. By clicking on a specific unit, the sectional plan for the floor within which the unit lies is displayed. In addition, other attribute information of the unit is also displayed (Cemellini, B. et al, 2020). The application using Cesium JS library visualizes the legal borders of shared objects, shared structures, and housing units. Following the LADM standards, the software solution produced in this study is an application that isolates the geospatial data model of spatial units from their accompanying ownership and rights information. Supporting documents, which include spatial sources, are linked to the appropriate spatial unit. Digital copies of supporting

papers are kept. The prototype is a web application that allows for an efficient workflow for 3D data storage and visualization of survey data as well as 3D models for strata registration.



Extracted sectional property plans and area list for registration prepared for from the process. These documents were used in the model as supporting documents for the sectional properties units.



4. CONCLUSION

The results of this study show that the 3D product can support the registration of sectional properties, collection of land-based taxes and the integration with the local NLIMS. This is the first time this kind of model has been developed in Kenya and the authors believe that it can form a good basis for the development implementation of a local version of the LADM

registration of real properties, and facilitates registration of complex 3D property situations, and provide a intuitive user interface for 3D spatial visualization and virtual reality modeling.

REFERENCES

- Stoter, J.E. 2004: 3D Cadastre. PhD Thesis, Delft Technical University, the Netherlands.
- Thompson, R., van Oosterom, P., Karki, S., Cowie, B. (2015). A Taxonomy of Spatial Units in a Mixed 2D and 3D Cadastral Database. FIG Working Week 2015 – From the Wisdom of the Ages to the Challenges of the Modern World. Sofia, Bulgaria.
- Van Oosterom, P. (2013). Research and Development in 3D Cadastres, Computers Environment and Urban Systems (2013)
- ISO (2012). ISO 19152:2012 Geographic Information – Land Administration Domain Model (LADM), Version 1 December 2012 (Standard Available from the ISO Webshop).
- Pokswinski, S.; Gallagher, M.R.; Skowronski, N.S.; Loudermilk, E.L.; Hawley, C.; Wallace, D.; Everland, A.; Wallace, J.; Hiers, J.K. A simplified and affordable approach to forest monitoring using single terrestrial laser scans and transect sampling. *MethodsX* 2021, 8, 101484. [Google Scholar] [CrossRef]
- Huang, R., Fang, C., Qiu, K., Cui, L., Dong, Z., Zhu, S. and Tan, P., 2021. AR Mapping: Accurate and Efficient Mapping for Augmented Reality. arXiv preprint arXiv:2103.14846.
- Çağdaş, V., 2013. An application domain extension to CityGML for immovable property taxation: A Turkish case study. *International Journal of Applied Earth Observation and Geoinformation*, 21, pp.545-555.
- Vučić, N., Mađer, M., Vranić, S. and Roić, M., 2020. Initial 3D cadastre registration by cadastral resurvey in the Republic of Croatia. *Land Use Policy*, 98, p.104335.
- Drobež, P., Fras, M.K., Ferlan, M. and Lisec, A., 2017. Transition from 2D to 3D real property cadastre: The case of the Slovenian cadastre. *Computers, environment and urban systems*, 62, pp.125-135.
- Crommelinck, S., Bennett, R., Gerke, M., Nex, F., Yang, M.Y. and Vosselman, G., 2016. Review of automatic feature extraction from high-resolution optical sensor data for UAV-based cadastral mapping. *Remote Sensing*, 8(8), p.689.

3D Cadastral Modelling for Registration of Sectional Rights, Tax Collection and Integration into the National Land Information Management System in Kenya (11289)

Benard Odhiambo, Gordon Okumu Wayumba, Japheth Nyandoro, Kipchumba Evans and Julia Wakaba (Kenya)

FIG Congress 2022

Volunteering for the future - Geospatial excellence for a better living

Warsaw, Poland, 11–15 September 2022

Nex, F. and Remondino, F., 2014. UAV for 3D mapping applications: a review. Applied geomatics, 6(1), pp.1-15.

Lim, S.H., Choi, K.M. and Cho, G.S., 2020. A study on 3D model building of drones-based urban digital twins. Journal of Cadastre & Land InformatiX, 50(1), pp.163-180.

Cemellini, B., van Oosterom, P., Thompson, R. and de Vries, M., 2020. Design, development and usability testing of an LADM compliant 3D Cadastral prototype system. Land use policy, 98, p.104418.

Višnjevac, N., Mihajlović, R., Šoškić, M., Cvijetinović, Ž. and Bajat, B., 2019. Prototype of the 3D cadastral system based on a NoSQL database and a Javascript visualization application. ISPRS International Journal of Geo-Information, 8(5), p.227.

CONTACTS

Benard Odhiambo

8teq Solutions
Complex Building Quarry
Drive
Nairobi
KENYA
Tel. +254717374902
Email:
benard.odhiambo@8teq.co.ke
Web site: www.8teq.co.ke

Prof Gordon O. Wayumba

Technical university of Kenya
Haile Selassie Avenue
Nairobi
KENYA
Tel. +2540722775168
Email: gowayumba@gmail.com
Web site: <https://tukenya.ac.ke/>

Dr Okoth Ayugi

Technical university of Kenya
Haile Selassie Avenue
Nairobi
KENYA
Tel. ++254722276544
Email:
okothayugi@gmail.com
Web site:
<https://tukenya.ac.ke/>

Julia Wakaba

8teq Solutions
Complex Building Quarry
Drive
Nairobi
KENYA
Tel. +254791049498
Email:
julia.wakaba@8teq.co.ke
Web site: www.8teq.co.ke

Japheth Nyandoro

8teq Solutions
Complex Building Quarry Drive
Nairobi
KENYA
Tel. +254717974899
Email:
japheth.nyandoro@8teq.co.ke
Web site: www.8teq.co.ke

Brian Moenga

8teq Solutions
Complex Building Quarry
Drive
Nairobi
KENYA
Tel. +254707672049
Email:
brian.moenga@8teq.co.ke
Web site: www.8teq.co.ke

Evans Kipchumba

8teq Solutions
Complex Building Quarry
Drive
Nairobi
KENYA
Tel. +254706019606

3D Cadastral Modelling for Registration of Sectional Rights, Tax Collection and Integration into the National Land Information Management System in Kenya (11289)

Benard Odhiambo, Gordon Okumu Wayumba, Japheth Nyandoro, Kipchumba Evans and Julia Wakaba (Kenya)

FIG Congress 2022

Volunteering for the future - Geospatial excellence for a better living

Warsaw, Poland, 11–15 September 2022

Email:
evans.kipchumba@8teq.co.ke
Web site: www.8teq.co.ke

3D Cadastral Modelling for Registration of Sectional Rights, Tax Collection and Integration into the National Land Information Management System in Kenya (11289)

Benard Odhiambo, Gordon Okumu Wayumba, Japheth Nyandoro, Kipchumba Evans and Julia Wakaba (Kenya)

FIG Congress 2022

Volunteering for the future - Geospatial excellence for a better living

Warsaw, Poland, 11–15 September 2022