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SUGGESTED FRAMEWORK FOR INTEGRATING ELEVATION DATA INTO EXISTING PLANIMETRIC CADASTRE SYSTEM IN NIGERIA

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ABSTRACT

Issues associated with urbanization, food security and climate change, are components of sustainable global agenda that require effective and efficient land management concepts, methodologies and policies. Applications of 3D cadastre concept to land management and administration require a suitable and flexible template. 3D cadastre is a concept of land administration that allows registration of rights in 3D topological space with emphasis on the three (3) component axis (X,Y and Z) as spatial consideration; whereas, the practise of the present legacy cadastral survey restricts right ownership in 2D (X and Y). In view of this, there's need therefore for the inclusion of height values into all existing 2D cadastre in anticipation of 3D cadastral survey in the near future. This paper proposed a template that adopts the framework of fit-for-purpose concept for integrating height values into existing 2D cadastre. The template considers the methodology for height data integration ranging from technical activities (data acquisition, processing and accuracy assessment) and institutional issues to legal framework. The strategy is targeted at ensuring 3D physical boundary demarcation in geometric space (2.5D) in a uniform spatial reference system that comprehensively defines location in the three (3) component axis. The study further established the possible comparative advantages of the methods of height data acquisition and concluded that the choice of methods for 3D cadastre implementation would be affected by cost, quality, time and size required for the project implementation.

Key words: 3D Cadastre, Mapping, Land administration, Fit-For Purpose, Land Administration Domain Model, Elevation Data

INTRODUCTION

The need for good land governance has been a major national discourse in Nigeria in recent time. Major opinions have evolved in the media that the financial crisis originating in the Nigerian states is as a result of lack of implementation and enforcement of land regulations; leading to poorly managed land, limited land information, and has culminated to poor risk management and decision making. The country's existing 2D cadastre is limited in providing and meeting the data requirements for 3D cadaster, this is because the 2D cadaster is designed to convey only the extent and not topography of land holdings. Efforts geared towards building good land governance that will drive a sustainable development requires a good and versatile 3D cadastre data framework. However, academic discourse on 3D cadastre in Nigeria is still nascent.

Few studies exist on necessity and requirements for implementation of 3D situation in Nigerian major cities, possibility of 3D cadastral for efficient land governance and geospatial requirement for 3D cadastre implementation, though issues relating to methodology for height data integration is sufficiently not being addressed; this may be attributed to existing laws and regulation guiding cadastral practise in Nigeria only recognizing land demarcation in planimetric system only (X and Y components of spatial dimension) with fixed land boundary (Abidoye and Oluwadare, 2019).

Height is fundamental to 3D cadastre development, complex situations do arise for which it is clear that the current 2D system is not able to represent. Such interests include registering rights of individual for ownership of volume-space within multilevel structures, registration of rights for underground utilities among others especially in urban cities. Methodologies for the third dimension determination for a convenient migration of existing 2D cadastre data into full 3D system should consider the cost, time and resources required for fresh survey on old parcels. Abidoye and Oluwadare (2019) advocated the need for professionals and government agencies in land matters to speak more on the benefit of implementing 3D cadastre and recommended deliberate efforts that will provoke both the public and private participation towards a legislatively reformed cadastral practice for best practices of land governance. Dabiri (2013), Babalola *et al* (2015), Abidoye and Oluwadare (2019) had advocated elevation value as a spatial consideration for 3D implementation in Nigeria but the studies did not give any insight into the approach that can be considered for flexible height determination.

Generally, the height of a point on the earth's surface can be determined by spirit, trigonometric and GPS leveling. The height of a point on the earth's surface is geometrically defined as the distance from the point along the reference line to the reference surface. According to Zhiping (2014), the different reference lines or reference surfaces for heights will constitute different height systems. Obviously, the height of the same earth's surface point in different height systems is expected to vary. Zhiping (2014) further stated that for any height system to be chosen, the following requirements need to be fulfilled:

i. The height of the point is required to be unambiguous and independent of the leveling path.
ii. In practice, when converted to the adopted height system, the corrections to the measured height differences for points in a limited area should be very small so that they can possibly be ignored while dealing with low-order leveling data.

iii. From the geometric problem-solving perspective, the ellipsoidal height is the sum of the measured height and the geoid height; thus it requires that the adopted height system should make the method for determining the difference between the geoid and the reference ellipsoid (normal ellipsoid) sufficiently rigorous and convenient, as well as practicable.

Whichever method is used, a reference surface (zero-elevation surface) and reference line (the line along which the height is measured) will be involved. The height determined regardless of techniques must be referenced to the Mean Sea Level (MSL). Only height determined based on the MSL referencing can be useful for geospatial application. MSL is the zero-elevation surfaces to which elevations or heights are referred; it is called a vertical datum. Traditionally, surveyors and mapmakers have adopted the average (or mean) sea level as the definition of zero elevation, because the sea surface is available worldwide (Whalen, 1985).

Aksoy (1993), described the MSL as a close approximation to surface defined by gravity (geoid), which is the true zero surface for measuring elevations. Because the geoid surface cannot directly be seen, then, the actual measurement of heights above or below the geoid surface cannot be done. A gravity measurement is thus carried out to model the geoid mathematically. For practical purposes, it is assumed that at the coastline the geoid and the MSL surfaces are essentially the same. Nevertheless, measure heights on the inland are done relative to the zero height at the coast (MSL) (Schimitt, 1986; Aksoy, 1993; Erkaya, 1993). To understand the differences in height measurements and their representation on maps and charts or on the display of a piece of equipment, it is necessary to understand the differences between topographic surface, ellipsoidal surface, and the geoid as illustrated in figure 1.

Generally, height for cadastral, engineering and construction purpose are usually determined using the topographic surface as the surface for measurement reference to the geoid. The geoid is the model that best fits the earth surface and shape, and the closest surface to the topography.

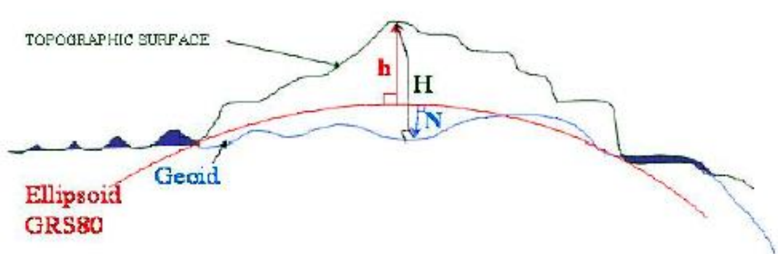

Figure 1: Relationship between geoid, ellipsoid and the topography

The first publication on 3D cadastre was released in 1998 by International Federation of Surveyors (FIG) Commission 7 with the mandate to identify trends in cadastral fields and to suggest a direction to which the cadastre might go from 1994-2014 (twenty years). This led to the emergence of "Cadastre 2014" (FIG, 2014). Having seen the limitations of 2D cadastre in solving complex property rights, restrictions and responsibilities; then 3D cadastre was proposed with a fit-for-purpose (FFP) concept for countries of the world. Studies have shown the importance of integration heights into 2D cadastre (See Babalola etal. 2015, Hrvoje etal, 2012, Galina etal, 2012).

In the study of Galina etal, 2012; the Teledom building in Russia with multiple level, underground parking and large number of units with various types of registered rights was modeled in 3D. The construction of the building was such that one part overhangs the road and another part is located above other building located on a neighbouring parcel. The building was modeled such that only the basement is represented within the land parcel on a 2D map. The study was conducted based on 3D cadastral model using Land Administration Domain Model (LADM) with International Standard Organization (ISO FDIS) 19152 on which the development of a web-based prototype for 3D cadastral visualization is anchored. The developed prototype consists of a 3D viewer that shows the cadastral objects in 3D space and offering permission to make selections based on stored data regarding cadastral number, name of the owner, number of rooms etc.

Babalola et al. 2015 opined that implementation of 3D cadastre in Malaysia has improved keeping data for all available parcels together with information for the strata and stratum property ownership in multilevel surfaces. Study by Hrvoje etal, 2012 also shows elevation data as fundamental for 3D cadastre for real estate management development of visibility analysis calculation and valuation using a detailed 3D physical model.

However, the use of high rise buildings and construction of multi-level apartments and overpass structures in modern cities indicated a formal approach to registering any emerging rights along the vertical components. As a result of this, there has been evolution of Core Cadastral Domain Models like Social Tenure Domain Model (STDM) and Land Administration Domain Model (LADM) for the organization of emerging complex property interests within a 3D cadastral system.

The development of 3D cadastre that would provide a flexible means of managing such rights within the cadastral framework would require the inclusion of height component into both the existing 2D cadastre and future cadastral surveys. Hence, a successful implementation of flexible techniques of height determination for 2D legacy cadastre would undoubtedly be a realization of Cadastre 2014 (FIG, 2014). Therefore, the approach must envisage a methodology that is fit-for-purpose (Figure 2) in saving time, cost and capacity to yield desired accuracy. It must consider the flexibility of the method for data acquisition (spatial framework), management (institutional framework) and right registration (legal framework) (Figure 2).

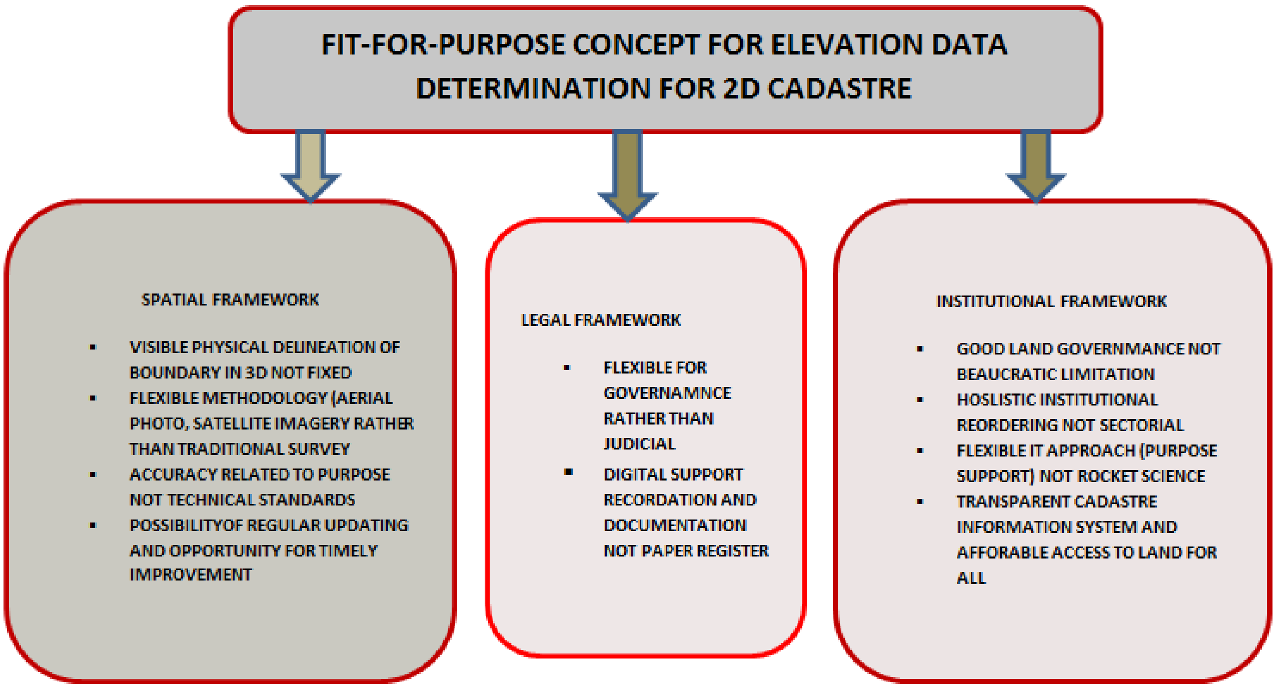

Figure 2: Basic framework for 3D cadastre implementation
Source: Adapted from Fit –for-Purpose manual (2018)

Spatial Framework For Elevation Determination For Existing 2d Cadastre

Geodetic framework for referencing is the foundational requirement for referencing in any survey project (boundary survey, engineering, and mapping). The proposed spatial framework revolves around methodologies of determining elevation data, the activities involved and the accuracy assessment as shown in figure 3, figure 4 and figure 6. Since spatial referencing for cadastral data cannot be compromised, adequate geodetic reference networks must be available for such activity so that land identification can be possible both for planimetric and altimetric coordinates. The proposed spatial framework was based on the

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possibilities of exploring methodologies of elevation data determination from SRTM, ASTER, Space photogrammetry product (existing DTM) and traditional ground survey product (topographic map) as presented in this paper. The general characteristics of adopted methodologies as proposed were categorized in Table 1.0.

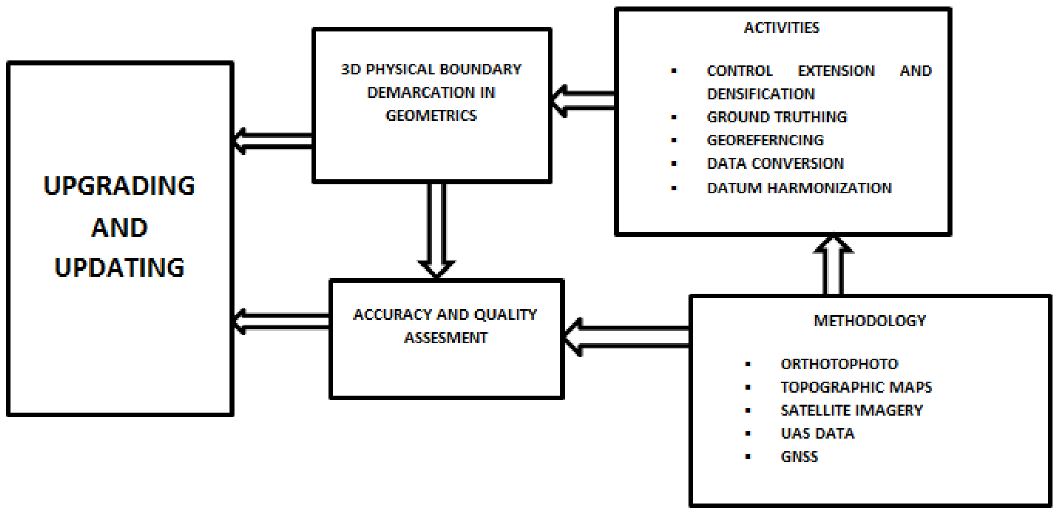

Figure 3: Basic spatial framework for 3D cadaster Source: Abidoye (2019)

Table 1.0: Characteristics of data sources for creating DTM

Collection method	Main characteristics	Examples	Typical accuracy
Ground survey	Highest accuracy; sampling density; high cost	DGPS systems, Tacheometry, levelling	<1m 0.001m-1m ≃ 0.001
Stereoscopic imagery	High sampling density; can be semi or fully automated; problems with vegetation	Aerial photography, Satellite imagery (e.g. SPOT and ASTER)	0.1m-1m 10m-20m
Laser scanning	Laser scanner is placed in the airplane which is GPS navigated; raw data need filtering and resampling before it can be used; it can penetrate tree foliage and record both surface of the vegetation cover ground	Airborne laser scanning (e.g LIDAR)	0.2m – 1m

Radar imagery	The lowest cost per km^2; requires ground control data; complex processing	Airborne Synthetic Aperture radar (e.g InSAR)	0.5m – 2m
		Spaceborne (ERS and SRTM)	10m – 25m

Source: Hengi *et al*, 2003

Topographic Map Method

Many data acquisition methods can now be used for the determination of elevation data for all existing 2D cadastre, but it is essential to consider its cost, time and quality before adoption. Elevation data extraction from topographic map requires large survey party especially in cases where control densification is required. This may be discouraging as a lot of time may be required to complete the task. However, in cases where high degree of accuracy of elevation data is required, the current topographic map of 1:50,000 cannot meet up spatial accuracy demand of height integration at large scale; therefore, a geometric framework for control densification and extension in third dimension is required. The fundamental concept requires the establishment of geometric framework for data acquisition for land data management system. These controls are expected to be established such that specific needs of 3D cadaster mapping are addressed where boundaries are properly delineated and topographic data are made available.

The procedure requires the professional skills of land surveyors and geodesist, the design of the framework must also consider density of controls and spacing of controls, accuracy required and the reference system. Vertical accuracy for this nature of activity should conform to second order requirement for vertical geodetic controls within the range of 1mm to 1.3mm at spaced distance of 5km to 8km in urban areas and 3km to 5km in rural and semi-urban area. Accuracy of vertical reference can be determined using the expression $\boldsymbol{b} = \boldsymbol{s}/\sqrt{\boldsymbol{d}}$. Where *d* is the approximate distance in kilometers and *S* is the standard deviation of difference of elevation data in millimeters.

Presently, there are few contour lines and spot heights on the current topographic maps in circulation, therefore, control extension and densification in X, Y and Z coordinates is important to facilitate acquisition of elevation data in this scenario. This suggest that geodetic survey using GNSS approach for the establishment of more geodetic controls with second order accuracy is required for quick migration from 2D to a full 3D cadastre in Nigeria. These controls would provide the benchmarks and should certainly enhance quality of elevation data extraction and generation especially in cases where interpolation is required. Sufficient availability of second order controls would help professionals and related organizations involved in spatial data acquisition, management and processing to have access to data required for base referencing for altimetric data generation.

Densified data points may also be used for georeferencing of the topographic map and then overlayed on the existing digital cadastral layout plan or the ortho rectified photograph. Elevation data of any existing cadastral layout can thus be extracted directly from the topographic map. However, in cases where sufficient controls are not available, topographic map conversion is thus required by vectorization. This implies that contour lines be digitized and corresponding elevation values of spot height of the topographic map can be stored, hence, overlayed operation can thus be performed where the digitized contour map is overlayed on the existing digital cadastral layout plan. To achieve any overlay, the datasets must be based on common spatial reference system along X, Y and Z coordinates.

Topographic survey of Nigeria was done in 1965 and the survey was based on the Nigeria local geodetic datum (Minna datum) of Clarke 1880 ellipsoid; the survey that establishes the geodetic controls is such that planimetric survey was done independent of the altimetric survey. However, the height system used for the survey is orthometric height system which is usually not compatible with ellipsoidal height system of the GPS. Usually, survey performed by GPS methods are always in 3D components (X, Y, Z) of WGS84 or International Terrestrial Reference Frame (ITRF 2008) and these components are usually geocentric coordinate systems, thus, it is required to transform those coordinates into local geodetic systems of Eastings and Northings.

To get height of the used benchmark in any system, Earth Gravitational Model EGM2008 can be used, the reference EGM2008 was also established on WGS84 ellipsoid. EGM2008 has been publicly released by the National Geospatial- Intelligence Agency (NGA) and can be accessed online at open sources. Hence, the availability of elevation values on both WGS 84 and local reference system (orthometric height in Minna datum reference) can facilitate the local and regional geoidal modeling.

Global Positioning System Method

In recent times, GPS survey, remote sensing and satellite technology allows the determination of the height values of any point on the surface of the earth Thus, integrating the third component (height) to the present legacy cadastre can be achieved adopting either classical or modern techniques. This in turn will help in solving the identified problems in land management system and city planning and will generally improve land administration and management in Nigeria. With the use of GPS, controls can be extended across existing planimetric cadastral layout, altimetric data determination for such planimetric cadastre data points using any topographic map referenced to orthometric height system would require height system transformation from orthometric to GPS ellipsoidal system and vice-versa. Height values required in either of the height systems can be supplied and queried online using the EGM 2008 model and corresponding results are displayed accordingly. The model that establishes the relationship between elevation from ellipsoidal height to orthometric elevation and vice-versa was given in figure 1 and equation 1.

h*= *H*+*N --- equation 1.0.

Where ***h*=** ellipsoidal height and ***H*=** orthometric height.

The geoidal height (N) is usually determine through local gravity survey for local geoid Modelling, but incase where local geoid does not exist, EGM2008 geoidal undulation is relevant for use but its accuracy must be well proven.

Digital Elevation Model Method

With remote sensing and satellite technology (Global Digital Elevation Models), 3D positioning is affordable in relatively short time. Elevation values are now generated from Global Digital Elevation Models using sensors in the space; this makes 3D positioning possible and affordable (Abidoye, 2019). GDEM from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER); Shuttle Radar Topographical Mission (SRTM) gives surface characteristics from which elevation data can be extracted. SRTM provides the highest accuracy of ±8.963 while ASTER data has accuracy of ± 10.406 as well (Abidoye, 2019) while existing data source like topographic map has the capacity to give accuracy up to ± 3.540 (Abidoye, 2019).

Abidoye (2019) opined that running GPS survey for all existing 2D cadastre in Nigeria would be difficult considering cost and time; alternative methods like SRTM and ASTER may be used in cases where 3D precise positioning may not be required. Global coverage nature of GDSM data allows extraction of elevation data of large coverage, though cheap and readily available, the procedures requires image preprocessing where by noise and cloud effects are removed (Table 3.0). Generally both satellite data acquired would cover both the global surface and thermal characteristics as well as land use and land cover characteristics. Therefore determining elevation data requires a thorough ground-truthing process whereby identifiable coordinated points are used to check the area of interest (Table 3.0).

However, GDEM is best useful in situations where selected points of interest are required, this is because terrain characteristics are naturally continuous hence elevation data are usually auto-correlated. Selecting elevation points of interest will reduce the effect of auto correlation and outliers can quickly be determined but usually not necessarily required to be removed. SRTM and ASTER data are usually produced with WGS84 reference system; therefore, datum transformation may not be required in areas where local datum has no significant consideration for spatial referencing.

Whereas, procedure for elevation value extraction from GDSM does not require establishment of ground controls for georeferencing (Table 3.0) ; since GDSM imagery are in digital format, data conversion (digitizing) is not required. The procedure also allows

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generating contour lines and spot heights at convenient intervals (unlike topographic map data) using spatial data management tools, contour intervals can be selected and chosen at will to satisfy specific demands regarding terrain characteristics of areas of interest. Further to this, SRTM and ASTER are open source software readily available with little or no financial implication; though users require internet to access the data.

Thorough assessment of extracted elevation data cannot be compromised in migrating from 2D cadastre to a full 3D in geometric space. Data quality should be assessed a priori and posteriori. Once the elevation data has been extracted, numerical statistical test like standard deviation, linear regression and least square analysis should be run on the data values to ascertain the absence of both random and systematic error. However, positional accuracy is also required to be determined using the International Organization for Standardization (ISO) data requirement with regards to completeness and logical consistency. Standard deviation should be used to determine the precision of extracted elevation values while the root mean square error (RMSE) should be used to determine data accuracy for extracted elevation values. Non statistical posteriori test is required on the surface models which are spatial products of the extracted elevation values. This test should include basically visualization of surface models generated from the extracted values of elevation. However, the model representation should be logically and carefully examined and be ensured to match the reality of the surface and terrain characteristics. Slope and aspect models should also be used to test quality of the extracted elevation data before final documentation. Summarily, procedure for data quality should include the following:

i. Quality dataset (elevation data) preparation procedures
ii. Spatial statistical processing of extracted elevation data
iii. Comparison of surface models representation and visualization
iv. Comparison and evaluation of both surface models representation and statistically processed data

RMSE is a common tool in statistics for estimating error in spatial dimensions. Moreover, elevation data obtained from different DEM sources can be compared with standard so as to determine an optimum approach for cadastral specifications. Vertical accuracy for data sources used in determining elevation data for a supposed spatially correlated scenario like a cadastral layout terrain data can be evaluated from the point of view that data points have strong and positive linear correlation, highest RMSE is not greater than N times of the mean of overall accuracy and the difference in the means RMSEs and the square root sum of RMSEs must have values within the limit of -1 to +1 and must conform reasonably well to the coefficient of linear correlation of data points. However, the

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comparison of expected accuracy, cost, time and coverage area among different methods of DEM determination is as shown in table 2.0.

Table 2.0: Comparison of different DEM Methods

Methods	Data accuracy	Speed	Cost	Application domain
Traditional survey	High (cm-m)	Very slow	Very high	Small areas
GPS survey	Relatively high (cm-m)	Slow	Relatively high	Small areas
Photogrammetry	Medium to high (cm-m)	Relatively slow	Relatively high	Medium to large areas
Space photogrammetry	Low to median (m)	Very slow	Low	Large areas
InSAR	Low (m)	Very fast	Low	Large areas
Radagrammetry	Very low (10cm)	Very fast	Low	Large areas
LiDAR	High (cm)	Fast	High	Medium to large areas
Map digitization	Relatively low (m)	Slow	High	Any area size
Map scanning	Relatively low (m)	Fast	Low	Any area size

Source: Li *et al*, 2005

Although, validation is often carried out by comparing the data with a set of ground control points, the quality of a DEM can also be ascertained by comparing the surface representation of DEM generated from geostatistical approach of interpolation and the terrain characteristics and reality. The merits and demerits of adopted methods as shown in table 3.0 were determined by a pilot test carried out adopting data sources from data sources from SRTM, ASTER, Space photogrammetry and traditional ground survey product (topographic map).

Table 3.0: Merits and demerits of suggested data source

Data source	Advantages	Disadvantages
SRTM and ASTER	▪ Ground controls are not required ▪ Georeferencing not needed ▪ Datum transformation not needed for referencing ▪ Data conversion is not required ▪ Data is open source with no cost implication	▪ Requires digital image processing ▪ Ground truthing required ▪ Requires Large storage space ▪ More suitable for large area ▪ Accuracy is low compared to topo map data

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Topographic Map	▪ Accuracy is very high ▪ Requires fairly large storage space compared to GDSM and Existing DTM	▪ Requires ground controls ▪ Spot height not usually sufficient ▪ Requires Geoferencing, digitizing (optional) ▪ Datum transformation is usually needed for referencing ▪ Require much personnel ▪ Requires high cost for ground control densification
Existing DTM	▪ Data directly extracted from digital elevation model ▪ Ground controls are not required ▪ Geoferencing not needed ▪ Datum transformation not needed for referencing ▪ Data conversion is not required	▪ Requires metadata ▪ Ground truthing is required ▪ Accuracy is low compared to topographic map data

Sources: Abidoye, (2019)

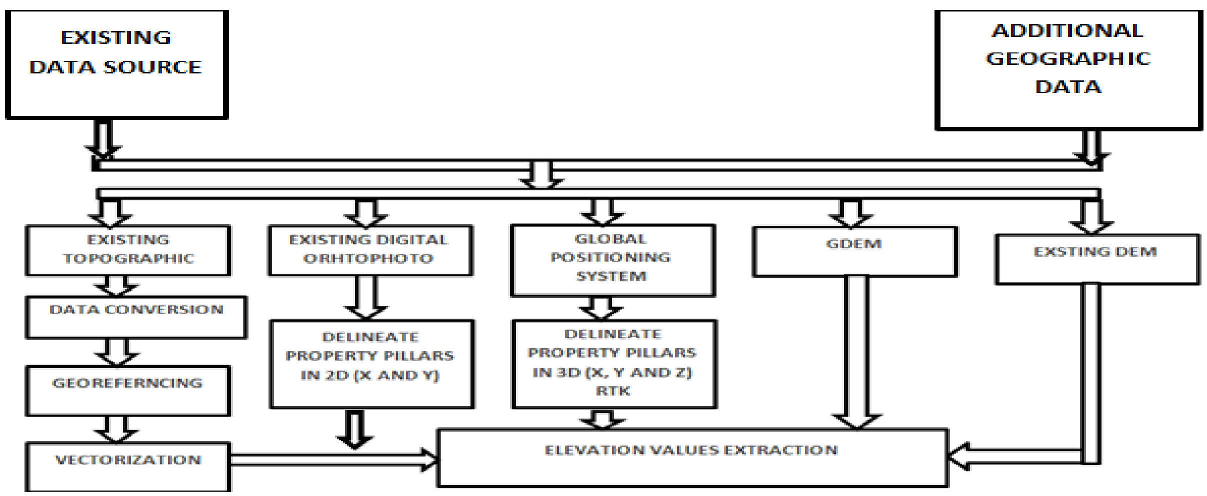

Figure 4: Framework for integrating elevation value into existing 2D cadastre

Sources: Abidoye, (2019)

Institutional Framework for Elevation Determination for Existing 2D Cadastre

Abidoye (2019) opined that the flexible approach to integration of elevation data into the existing 2D cadastre requires an institutional reordering. The reordering required may not be necessarily policy based, but a flexible framework that must give consideration to the underlisted concept of FFP.

i. Flexible and good land administration and management that focused on land right registration, tenure security, land values for taxation and city planning as well best regulatory practice rather than bureaucratic limitations and barriers.
ii. Institutional framework that affects entire procedure for land administration and management rather than sectorial.
iii. Simple, flexible technical approach rather than high-end rocket science and technology solutions.
iv. Cadastral information system with easy and affordable access for all.

Technical requirement for elevation data integration

The technical requirement should compose a viable Information and Communication Technology (ICT) that would give support to geo-earth digital environment such that both spatial and non-spatial requirement of the 3D cadastre would be accommodated in the database. Since data involved are large in size, software should be selected either to be purchased or develop with the availability of staff with required skills and capability to operate the system. In cases where software for data processing are not available or are expensive, the open source software should be used which also permits organizations and users customize the programs to suit their needs. Therefore, softwares should be capable of managing large area and the hardware components of the system should also have sufficient memory space and storage capability to accommodate large dataset. Furthermore, techniques for data storage and archiving should be completely digital and capable of regular updating as well as retaining previous dataset. The choice of instrument should be such that it will give the required accuracy. Therefore, Dual frequency Real Time Kinematics GPS is recommended for implementation. Hence, high level competent professional are needed to facilitate data acquisition due to the large volume of dataset involved. Therefore, in-house data acquisition system may not sufficiently meet the technical specifications and requirements of the level of accuracy required.

Dabiri (2013), Abidoye and Oluwadare (2019), envisaged the professionals that should be responsible for 3D cadastre data development, data acquisition, management and implementation as land surveyors, town planners, architects, estate managers and valuers, lawyers and engineers (civil, electrical and structural). However, each of the professionals has regulatory council that regulates the professional practice of all cadres in the profession. Their roles go with their professional training and expectations from the populace and the government; be it in the private practice or public service (Dabiri, 2013). Abidoye and Oluwadare (2019) advocated that the determination of spatial limits of spatial units in 3D (geometric and topological space) is expected to be achieved by methods of surveying and mapping. The land surveyors are expected to be responsible for this aspect of cadastral survey operation where positions and sizes of parcels of land are well defined in a geometric space with the names of the owner explicitly indicated Dabiri (2013).

Considering the size of existing 2D cadastre and future 3D cadastre survey, the available skilled manpower (government-employed land surveyors) may not be sufficient. Hence, outsourcing to both private surveyors and trained Para-surveyors may require more cost but certainly, data quality will be maintained. Further to this, the practice of cadastral across the country is gradually becoming digital. Although in most cases, not all available analogue data has been converted to digital, this is because of the rigor and finance associated with immediate replacement of analogous practise with digitization (Babalola *et al*. 2017). Cadaster data usually are voluminous and current paper files and document will require a lot of manpower, cost and time to be converted to digital format. Although, studies have shown that there are insufficient height data from the national topographic survey of 1965, and this may reduce the accuracy of elevation data extracted from existing topographic map.

The availability of ground controls in WGS 84 format (ellipsoidal height system) that was used for the georeferencing of orthophotographs in some States of the Federal Republic of Nigeria will facilitate quick extension and densification of benchmarks across the country provided the heights above or below the MSL is captured; this will certainly reduce the cost of Ground Control Point (GCP) establishment for referencing. However, for previous planimetric data that were based on Minna Datum (Clarke 1880 ellipsoid), datum transformation may be required to transform the height values from orthometric height system to ellipsoidal height system as earlier stated.

Suggested Framework for 3D Legacy Cadastre

Cadastral survey in Nigeria is a legal matter; hence its operation is legislated and captured in the constitution through the Land Use Act (Chapter 202 CAP.L.5). The law stipulates that all lands within a state (except land belonging to the Federal Government and its agencies) are vested in the Governor of that State who holds the land in trust for the citizen of the state and may so wish allocate such based on demand for either public use or private use. The constitution also vested in the state governors the power to revoke land for overriding public interest. The constitution further saddles the land surveyors with the responsibilities of spatial data acquisition, management and maintenance especially for production of the survey plan required for efficient land administration.

At present, the spatial requirement for survey plan production is limited to planimetric data alone; therefore, there's need for the government agencies and other stakeholders in land administration and management to champion the course of a constitutional cadastral reforms

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so that cadastre data registered in 3D geometric space (3D survey plans) (Figure 5) can be incorporated into the law as a registrable instrument (Abidoye and Oluwadare, 2019). Stakeholders are expected therefore to continually stress the limitations of the current 2D cadaster and advocate the benefits of integrating elevation values into the current system. This could be accomplished through public sensitization until legislative actions are taken to ensure challenges of national land administration in terms of registering rights in vertical direction are addressed (Abidoye and Oluwadare, 2019).

Legislative Acts are also important to ensure that the basic required data for processing of Certificate of Occupancy (Deed and Survey Plans) are always stored and retrieved digitally. However, it is important to caution that law maintains the traditional 2D practise for cases where 3D rights may not be applicable, the legal system should allow that the two spatial phenomena (2D and 3D cadaster practice) to operate legally either separately or simultaneously (Abidoye and Oluwadare, 2019).

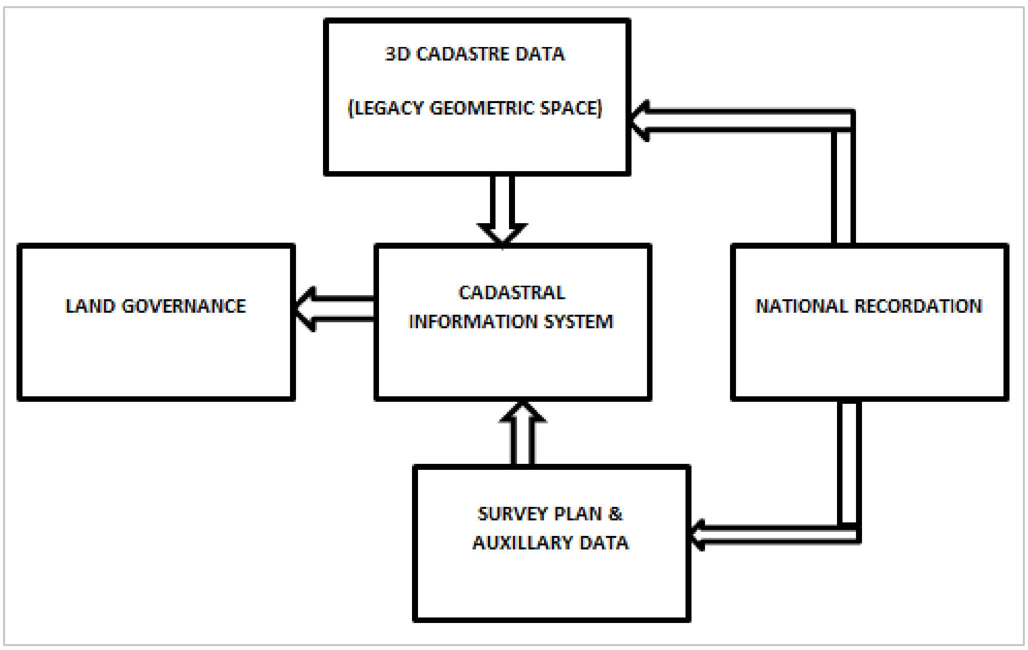

Figure 5: Legal framework for 3D cadaster.
Source: Author's field work (2018).

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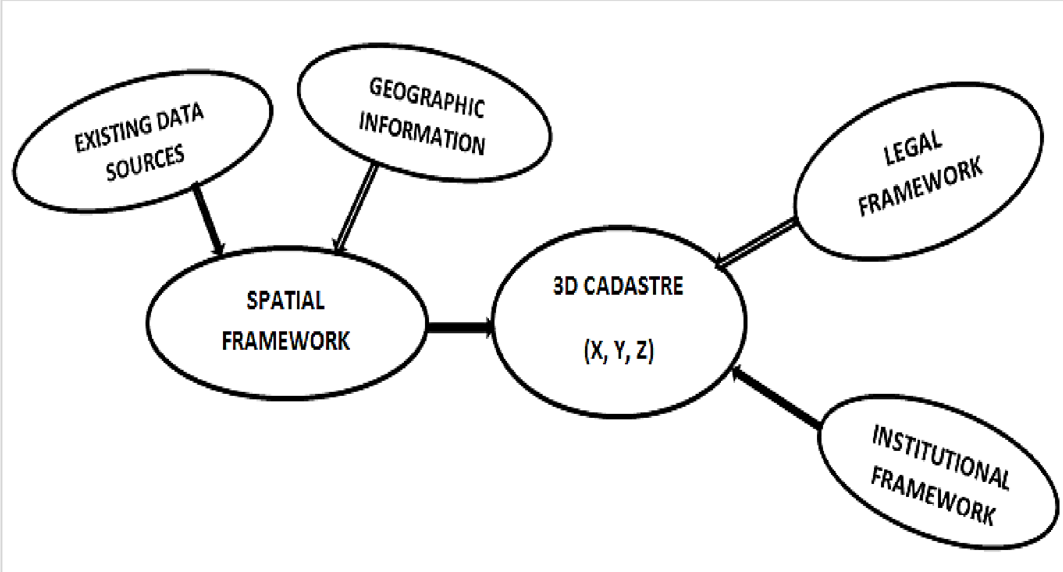

Figure 6: Suggested framework for upgrading existing 2D into 3D Cadastre
Source: Author's field work (2018).

Cost, Time and Quality Dimension of Methodology for 3D Physical Boundary Demarcation

3D cadastre may not be the ultimate solution to all the land governance problems; it is designed to initially meet the fundamental needs of society today with the capabilities to improve over time. Implementing 3D cadaster basically may require the consideration for the cost of the project, scale required (usually determined by size and accuracy), quality required (usually determined by accuracy and precision) and time. The direction of flow for achieving not more than four (4) basic project requirements for 3D cadastre mapping at an instance is shown in the triangle (Figure 7).

Usually, it is difficult to maintain cost, quality and time variables in a single project management; only two of this can be achieved at a time. Where cost is reduced, the quality of the project is usually compromised while efficiency of time is as well achieved. The cost of 3D cadastre implementation will be determined by the methodology to be adopted, nature of the terrain, required equipment, personnel, density of geodetic controls, spacing of geodetic controls and general logistics; while quality directly depends on the required accuracy and precision.

Furthermore, scale is an important requirement for any cadastral mapping as it establishes the relationship between map data and ground data. For any reasonable spatial analysis, the choices of scale should be considered important because the accuracy of such spatial analysis depends on it. The possibility of achieving cost, time and size at an instance is shown with the red arrows (Figure 7).

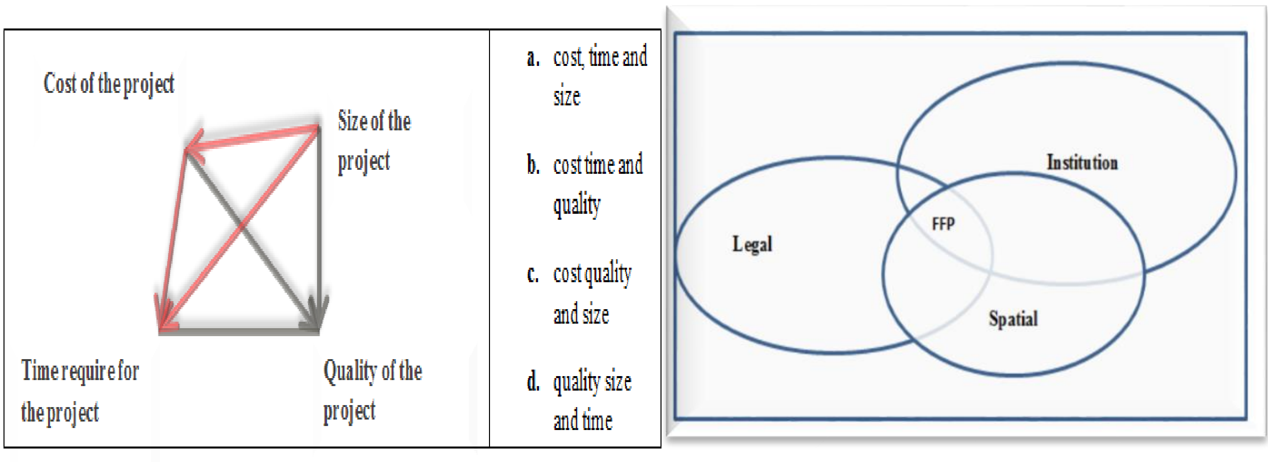

Figure 7: Proposed Fit-for-Purpose consideration for 3D cadastre project
Sources: Abidoye (2019).

Moreso, for the Fit- For-Purpose (FFP) approach for any adopted methods of implementation of the 3D cadastre, the three (3) frameworks discussed must be seen to agree with each other (Figure 6 and Figure 7). It implies that the legal framework must support the operations of the institution, while the spatial framework is also legalized so as to ensure a legacy spatial consideration for 3D cadastre and land governance. More on this, extracting elevation data from existing sources like GDEM is relatively cheap and available for large coverage area but low accuracy may be attainable (±16m absolute accuracy), whereas, extracting elevation data from topographic map dataset is also cheap and readily available with very high accuracy possibilities but procedures can be cumbersome and time consuming especially when the cadastre coverage is large and dataset are not available in digital format.

Photogrammetry approach can also be considered to be fairly accurate but the project execution budget may be expensive for developing nations like Nigeria though with less time consumed compared to the topographic map approach. However, any method adopted for FFP concept will compromise specific elements of less or no importance (time, cost, quality) in regard to the project execution (altimetric data determination and integration) while emphasis is laid on desired element of choice (Table 4.0). It therefore implied that any approach of height determination adopted will only fit a desired purpose at a time variable.

Therefore, adopting a methodology that reduces cost will certainly reduce the quality of the extracted elevation data; reduce the accuracy as well as time reduction for project execution. In cases where good quality elevation value, that is high accuracy, is to be maintained, the cost is expected to be relatively high. Indeed, high accuracy will be attained but project execution will possibly take much time especially where scope or extent of land coverage is relatively large.

Table 4.0: Possible advantages of methods based on of Fit for purpose approach

Method	Possible Cost	Coverage	Possible Accuracy	Possible Time	Possible Quality
GDEM	Low	Large	Low	Short	Low
Photogrammetry	High	Large	High	Short	High
Topographic map	High	Large	High	Longer	High

Source: Abidoye (2019)

Conclusion and recommendations

Integrating height values into existing 2D cadastre, the legal, institutional and spatial framework should be flexible enough to lay emphasis on important consideration for project execution regarding Fit-For-Purpose (FFP) approach. In other word the spatial consideration must be harmonized with legal and institution considerations. The legal framework should take into consideration necessary legal reforms that could enhance the upgrading of the existing 2D cadastre to 3D cadastre. Similarly, the institutional framework must emphasize capacity building, the flexibility of the process and the sustainability of the infrastructure.

Since digitization of spatial data has already been introduced to the concerned organizations and professionals, implementation strategy should be flexible enough such that elevation data can be easily stored within the domain of the existing 2D planimetric data in the database. The flexibility should allow the operating of both 2D and 3D system independently. This will allow a smooth operation of either of the two systems in case of any system collapse.

The adoption of methods for elevation data determination for existing cadastres in Nigeria will require that the state agencies responsible for cadastral data acquisition and management are allowed to control activities regarding geodetic control establishment and densification accordingly. Infrastructure for the upgrading of the existing 2D cadastre should be put in place by relevant government agencies and organizations. Fit-for-purpose concept of land administration is advocated for Nigeria cadastral system. This is necessary for a flexible implementation of 3D cadastre land administration policy.

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