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3D Cartographic Model And Animation of As-built Educational Landuse of UNIBEN, Nigeria

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ABSTRACT

The study focuses on 3-Dimensional (3D) cartographic modelling of built facility. A shift from 2-Dimensional (2D) to 3D cartographic animation recently emerged to solve problems of geodata perception and analysis. As a proof of concept, 3D of UNIBEN educational landuse was modelled from Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) data draped on GeoEye satellite image to give a 3D impression using ArcScene 10.1 Software. The height of each building was extruded from digitized footprint. From the 2D and 3D image maps produced, a campus navigation simulation and animation are geovisualized. Results of the study show that, besides the open land area of the university campus, staff residential quarters had the highest land use, followed by academic (lecture theatres and staff offices) and students' hostels respectively. The Faculty of Arts/Social Sciences had the highest building height of 16m and 5 floors respectively. The structural query of the 372 mapped building structures reveals 29 of them were 13m high. From the 3D as-built model, spatial information on each building (name, number of floor, height, use and spatial references) are obtained. From flight simulation, the 3D geovisualization of different perspective views of the campus revealed the huge beauty and spatial organisation hitherto unavailable in a traditional 2D map. The study is recommended for the implementation of a campus-wide efficient sustainable spatial planning and electronic street guide.

Keywords: 3D Animation, As-Built Mapping, Facility Management, Geovisualization, Spatial Analysis

I. INTRODUCTION

As used in this study, a map is a graphic representation (static or interactive) or scale model of spatial concepts or universe of discourse. Incorporated in a map is also the understanding that it is a "snapshot" of an idea, a single picture, and a selection of concepts from a constantly changing database of geographic information [15]. While maps are considered model of geographic realities, the International Cartographic Association (ICA) in 1995 described cartography as the art, science and technology of studying and making map [10]. Two dimensional (2D) maps are orthogonal (x, y), while three dimensional (3D) maps integrate height (z) thus regarded as a better way of representing reality than 2D maps [2]. Rendering 3D maps in a digital and animated form is an emerging trend in cartography. 'The introduction of on-screen maps and their corresponding databases resulted in a split between these functions. To cartographers it brought the availability of database technology and computer graphics techniques that resulted in a new and alternative presentation options such as 3D and animated maps' [12].

Applying 3D in facility mapping (FM) or as-built mapping enhances effective facility and infrastructural management. Conceptually, as-built map shows the spatial and graphical representations of the existing facilities and infrastructure within an area of interest. Thus, the concept of Facilities Mapping of built environment 'is the process of digitally identifying and mapping facilities and infrastructure with the explicit goal to improve operational management and planning tasks such as dispatching, inventory, and maintenance' [24].

To unimaginable extent, maps have such multiplicity of uses as anything that can be spatially conceived can be mapped and, thus, have nearly unrestricted potential utility. The introduction of computer graphics [5] in mapping has created a more robust platform for Geographic Information Systems (GIS) that has led to a different dimension from 2D orthogonal representation of geographic reality to 3D representation [17]. The making of maps from Remotely Sensed Images such as multi-spectral images (e.g., GeoEye, NigeriaSat-2, IKONOS, SPOT), Laser, and other terrain measuring sources such as SONAR and SRTM as source of height information have all created the added advantage of rapidly producing maps in a way usually impossible [14]. In facility mapping of geographic phenomena such as building infrastructure, the relatively accurate coordinates (x,y) are basic requirements in order to work with them in a GIS environment. The shift or outright embrace of 3D modeling or 3D geovisualization (geovisual analytics) of geographic phenomena helps to better appreciate the phenomena being represented because of the additional height information as against the 2D orthogonal topographic mapping.

Today, the concept of 'geovisual analytics' [21] and 'information visualization' [3], [22], & [19], have both become a popular multi scenario mapping in 3D animation tool because it offers interactive access to multiple alternative graphic representations that stimulate (visual) thinking about geospatial patterns, relationships and trends, and as such supports knowledge construction [13]. In Cartographic animation and geovisualization, Dykes, MacEachren and Kraak stressed that geovisual analytics integrates approaches from scientific visualization, digital maps, image analysis, information visualization, exploratory data analysis (EDA) and GIS to provide theory, methods and tools for visual exploration, analysis, synthesis and presentation of geospatial data [6].

Studies on 3D facility and built-environment mapping abound in literature. For instance, Tamada *et al.*, in 1994 [20] developed an efficient 3D facility management system based on the spatial data structure (MD-tree). In the system, 3D objects in a city are semi-automatically generated from 2D-maps by using appropriate rules. This corroborates with the capability of modeling a walkthrough facility for efficient emergency management in a 3D cartographic environment as argued by kwan and Lee [13].

In remote sensing applications, Navatha, Venkata-Reddy and Pratap developed a 3D Modelling of NIT Warangal Campus Using GIS and High Resolution Satellite Data [18]. A similar study was done by Amhar *et al.,* on the generation of true orthophotos using a 3D building model in conjunction with a conventional Digital Terrain Model (DTM) [1]. Ideally, usual orthophotos do not place general 3D objects (buildings, bridges, etc) on their geometrically correct positions because conventional algorithms are based on 2.5D DTM thus limiting significantly the possibility of describing the real 3D shape of the objects and inhibiting the correct calculation of visibility.

Unlike Amhar*et al.*, [1], Frueh, Jain and Zakhor in 2005 developed a set of data processing algorithms for generating textured facade meshes of cities from a series of vertical 2D surface scans and camera images [8]. This is obtained by a laser scanner and digital camera while driving on public roads under normal traffic conditions and detecting dominant buildings. Applying the above steps to a large set of data of downtown Berkeley with several million 3D points, Frueh *et al.,* were able to obtain a texture-mapped 3D model. Geovisualization work of Harrower and Fabrikant [9] is noteworthy.

In Nigeria for example, Isioye, Aliyu and Nzelibe [11] carried out a 3D modeling of part of Ahmadu Bello University main campus in Nigeria using GIS and Google Earth satellite data. Generating shape file for the extracted buildings from a georeferenced image, the height of each building was added to the database as an additional field from which the extrusion of the height of the digitized buildings in ArcMap were carried out using ArcScene/ArcGIS software. A texture map of the senate building was carried out using the Google sketch up software. The developed 3D model was analyzed using attributes representing the characteristics and functionality of infrastructural facilities and resources of the campus. This reiterates the efficacy of rendering geographic reality in 3 dimensions.

From previous studies, we may infer that the various 3D modeling of geospatial data, especially building and their façade in particular, are carried out using relevant integrated modeling or mapping technologies such as CADD, GIS, GPS, among others. Although all maps should have a legend to explain their contents, it is even more important to obey cartographic law for an animation [12] especially when dealing with educational facility maps.

In addition, relevant studies on visualization of time series data, animated cartography and scientific visualization respectively includes those of Monmonier [16], Campbell *et al.,* [2]; DiBiase *et al.,* [4], and more recently, Harrower and Fabrikan's study on the role of animation in geovisualization [9]. The above authors' researches reiterate the emerging role of animation cartography in effectively and efficiently communicating reality especially to amateurs in geoinformation.

Some examples of facilities include utilities (gas, water, telephone, and electricity), airport siting, transport planning and building infrastructure. In the past, when the need for facility map arose, a team of surveyors and draftsmen would combine skills to develop such a map. The steps for a successful operational strategy is based, among others, on facility mapping system which enhances the collection and integration of information on organizational assets such as building infrastructure parameters like number of floors, height and usage.

The core of the FM system is, therefore, built around computer- aided drafting and design (CADD), Geographic Information Systems/Sciences (GIS) and Global Positioning Systems (GPS) technologies - especially for georeferencing base images for mapping. Regardless of ambiguity in terminologies uses, terms such as AM/FM (automated mapping/facilities management) and network management systems are essentially the same technology.

The major advantages of FM are that it facilitates quick database update, query and information that are useful for resource allocation, service dispatching, inventory, and maintenance. Nevertheless, analytical studies such as network analysis and catchment area analysis are possible with FM systems. GPS also play a major role in facility management because it is useful for geo-location of facilities aimed at effective management. It also enhances the visualization of spatial and temporal information in a GIS [7].

1.1 Statement of problem and Justification for the Study

To demonstrate the geospatial significance of emerging trends in cartographic animation, we used Ugbowo Campus of University of Benin, Benin City, Nigeria being one of the oldest campuses among the Federal Government owned Universities in Nigeria. The campus has vast land resources and less than half of it has been fully developed for human habitation and academic purposes. More so, there is currently a dearth of requisite spatial dataset and format for effective facility and infrastructure management, and the spatial planning of the available land space for quality building development. The traditional cadastral maps currently available to the university only show the land area and planned uses in two dimensions (x, y). It is hoped that a 3D as-built and facility map of the campus will cartographically provide a complete model of the visual dimensions of man-made features, enhance better interpretation and comprehension of dimensions of features, increase capacity of rendering of buildings and mapped features in three dimensions, etc. Administratively, it will better serve areas such as navigation, city aesthetics and spatial planning, documentation of cadastral information, and street guides, etc. Therefore, developing a 3D as-built map for the campus will provide vital dataset currently not available for the efficient spatial planning, electronic campus street guide, and infrastructural development and management of the citadel of learning. Cartographic animation gives a better impression that last longer in the memory of the viewer [2].

1.2 Aim and Objectives

The study aims at developing a 3D digital database and cartographic model for managing a built environment.

The specific objectives are to:

i. map and carry out the spatial analysis of landuse activities in the campus*;*
ii. produce 2D and 3D as-built maps of the study area;
iii. carry out a 3D rendition of the building infrastructures and account for the angular

perspective parameters used for navigation animation; and

iv. Validate the positional accuracy of mapped facilities using Google Earth platform.

1.4 The Study Area

The University of Benin (UNIBEN) is one of Nigeria's federal universities founded in 1970. It is located in Benin City; Edo State, Nigeria. The study area (Figure 1) spans between Longitudes $5^0 36'24.8"$ E to $5^0 37'55.4"$ E and Latitudes $6^0 23'33.4"$ N and $6^0 24'27.3"$ N respectively.

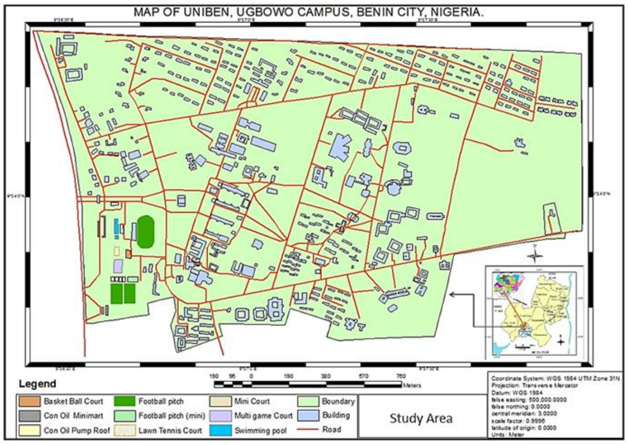

Figure 1: The Map of the Study Area (Source: Author, 2014)

The university started as an Institute of Technology and was accorded the status of a full-fledged University by National Universities Commission (NUC) on 1st of July 1971(www.uniben.edu) [23]. The University has grown spatially and structurally over the years hence the need to have a digital cartographic profile for effective infrastructure management.

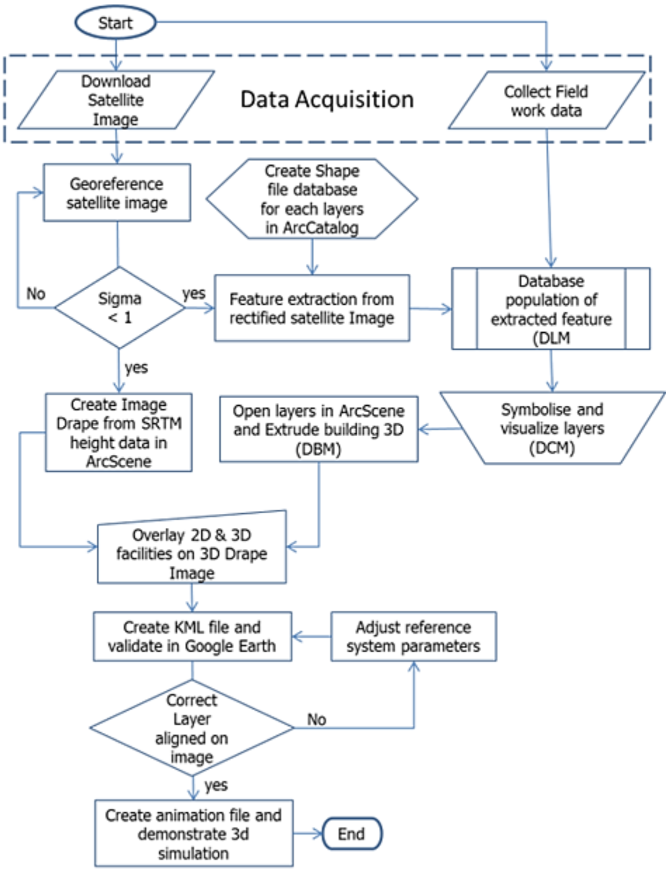

Figure 2 : Methodology Workflow using Unified Modeling Language (UML)

II. METHODS AND MATERIAL

2.1 Study Methodology Workflow

The workflow methodology used in this study is illustrated in figure 2. The vector data (facility map) was captured as digital landscape model (DLM) and features cartographically symbolized as digital cartographic model (DCM) as shown in Figure 2.

2.2 Data Collection and Sources

The data for this research were obtained mainly from two sources: primary (plate 1) and secondary sources (figure 3). The primary sources of data collection include field work and discussions with architects. During the fieldwork, direct field observations and inventorying of buildings and other facilities together with their corresponding height/depth and number of floors information were undertaken (plate 1).

Plate 1: Observation of building heights

Figure 3b: 3D drape image on DEM resampled

The data was further computerized and integrated into the digitized data (shapefiles) generated from the georeferenced image using ground control points of Digital Globe image (GeoEye) obtained from online Google Earth image platform (figure 3). The UTM, WGS84, Zone 31 parameters were used as these correspond with the primary projection information used in Google Earth.

Plate 2: Sample photo views of the mapped buildings (Source: fieldwork, 2014)

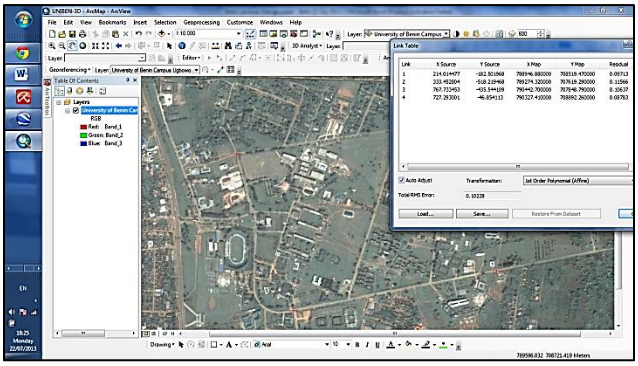

Figure 3a : Georeferencing interface

2.3 Data Analysis and Presentation Techniques

The shape files were digitized from the boundary-clipped rectified image (sigma 0.10228, based on 1st order polynomial [affine] transformation). Table 1 shows the generated datasets.

Having generated the shape files, their attribute information such as building height, number of floors and attribute names were entered accordingly.

Table 1: Description of generated shapefile datasets

Layer	Shape	Description
Flower	*Point*	Flowers planted within the University
Road	*line*	All roads including tarred, earth and footpaths
Boundary	*Polygon*	The study area extent
Landuse	*Polygon*	The various uses to which UNIBEN land area is put such as administrative, religious, academic, sports, health center, special centers, plantation, library, SUG, UDSS School, Banks or commercial, open land, Staff quarters, and students hostels.
Building	*Polygon*	All building facilities such as faculties, departments, lecture hall, quarters, special, auditorium, bank buildings.
Landmarks	*polygon*	These include facilities such as football pitch, swimming pool, petrol station and basketball pitch

For the terrain information, the SRTM raster DEM data was used to generate elevation model from which the satellite image was draped to model the surface of the study area. All the above were done using ArcMap. The study area landuse and 2D maps were visualized and their cartographic marginal information such as the north arrow, the scale bar, legend, coordinate system and the producer information were also done using ArcMap layout view.

For the 3D building foot print rendition, the shapefiles were geovisualized using ArcScene 3D geovisualization environment of ArcGIS 10.1 software. The vertical exaggeration of each building was multiplied by 3 'scale factor' for spontaneous recognition of height above terrain. The various buildings were assigned colours based on their height. The 3D point graphic symbol for flower was also used to give the flowers a 3D perception while the swimming pools' depths were extruded using negative values below the normal terrain level. To appreciate the general 3D facilities mapping, all the layers were overlayed on the 3D drape image as their respective base height.

To validate the spatial alignment and positional accuracy of the generated dataset, the shape files were converted using the Keyhole Markup Language (KML) conversion toolbox – '*layer to kml'* in ArcGIS software environment. A 500 scale range was used for all the datasets converted while the boundary shape file was used as the layer "extent properties".

The 3D facilities simulation and navigation animation was carried out using the Animation Toolbar in ArcScene. Each respective scenes for animation and their corresponding angular perspective parameters such as *display time*, *name of camera key frame, targets X, Y and Z, Azimuth, inclination, and roll* were captured using the capture button and stored using the ArcScene Animation Manager. The final file was exported and saved using .AVI extension for video. The resulted animation was played using the animation control player as well as the Window Media player as alternative video player software. The result is currently published online for visualization and validation of concept.

III. RESULT AND DISCUSSION

3.1 Landuse pattern of University of Benin, Ugbowo Campus.

For administrative and planning purposes, the use to which a piece of land is put is aimed at maximizing landuse benefit. Knowledge of these use(s) with respect to landmass is indispensable. Figure 4 shows the landuse map of the study area with the building facilities overlayed on top. From figure 5, we can deduce that open land landuse is the highest landuse closely followed by staff quarters (senior and junior put together) while academics and students' hostel follows sequentially. It is obvious from the landuse map that proper planning need to be done in order to maximize the potentials of the available land.

3.2 2D facility and image map visualization of the study area

Result of the as-built map of the study area shows that out of the total 3442302m^2 landmass, building infrastructures occupy about 282531m$^{2.}$ (See figures 5 and 6 respectively).

3.3 3D renditions of the building infrastructures, angular perspective parameters and time duration for navigation animation

Result of the 3D building infrastructure mapping (figures 9 and 10) shows that, the tallest building in the citadel of learn is the faculty of Social Sciences and Arts office buildings with a record of 16m height. This is closely followed by the Auditorium with 14m while for the 13m height buildings we have the school of medicine, faculty of law, hall 2, 3 and the blocks of flats. For example, resulting from the SQL query, out of the 372 buildings mapped, only 29 of them have building height of 13 meters above the terrain (figure 9).

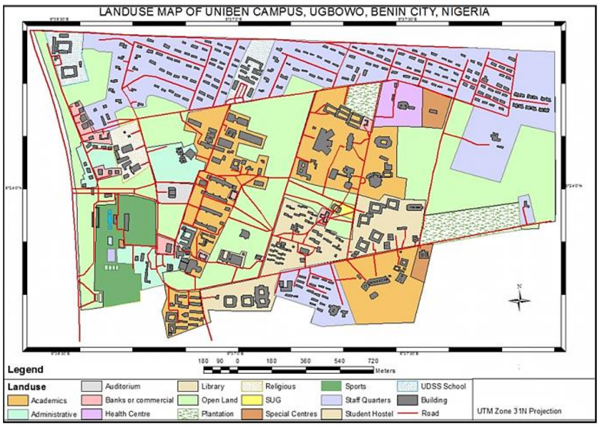

Figure 4: 2D Landuse Map of University of Benin Ugbowo main Campus

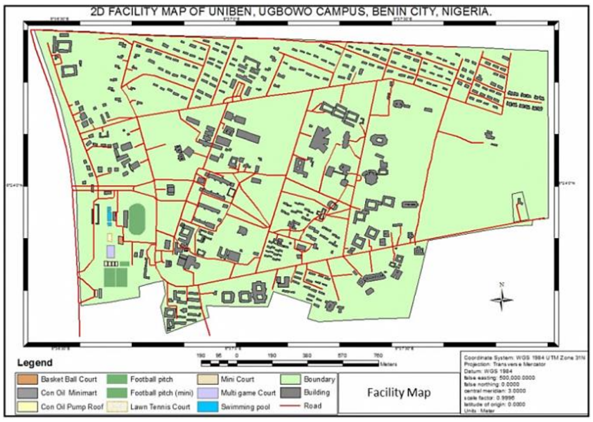

Figure 7: 2D As-built Map of UNIBEN Ugbowo Campus

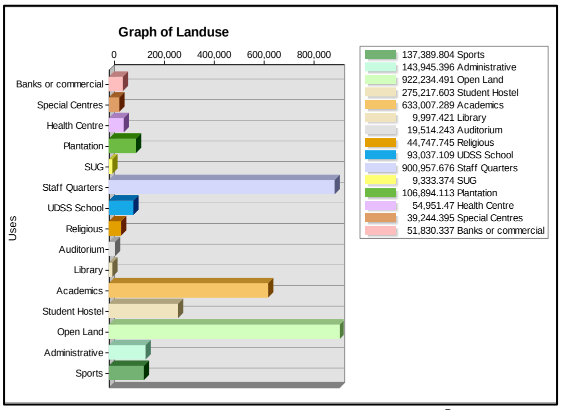

Figure 5: Bar Graph of Land Use Extent (m^2) in Ugbowo Campus

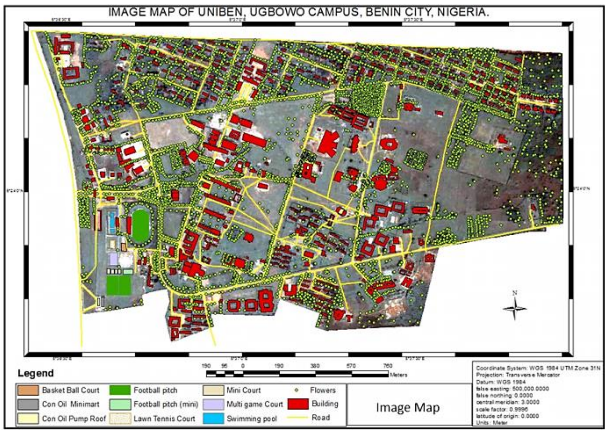

Figure 8: Image Map of UNIBEN Ugbowo Campus

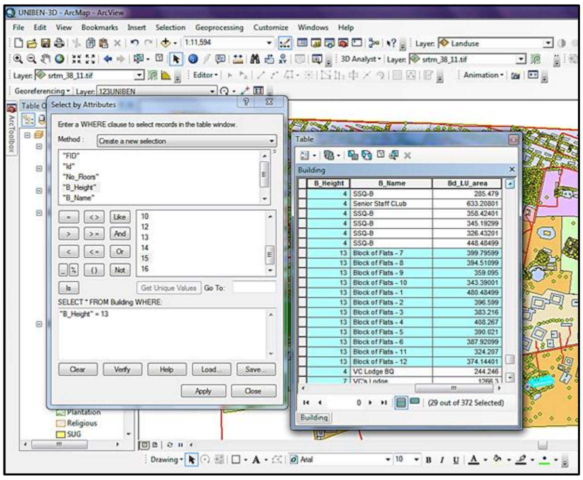

Figure 6: SQL Result of Map Query of all buildings height > 13m

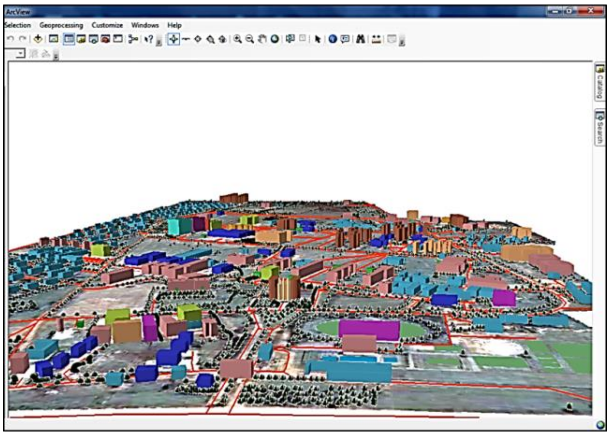

Figure 9: Overlay of Extruded 3D building Facilities on Satellite Image

3.4 Positional Accuracy validation of UNIBEN facility map using Google Earth viewer

Figure 10 shows that the KML converted geovisualized data fell in their appropriate locations in Google Earth based layer thus validating reliability and the positional accuracy of the modeled 3D dataset for further use.

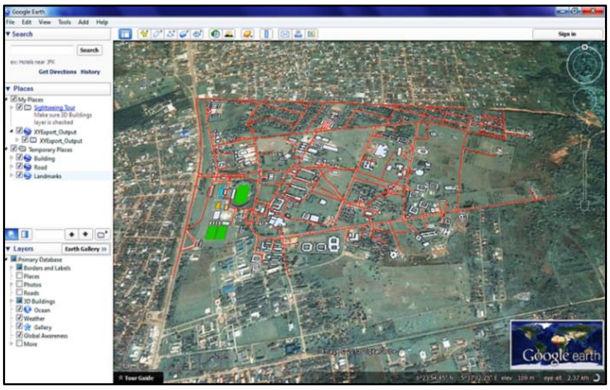

Figure 10: KML 3D Data Positional Accuracy Validation in Google Earth

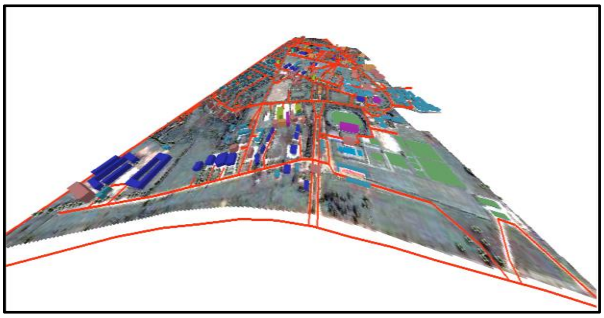

Figure 12: A Bird view snapshot of 3D flight navigation animation of UNIBEN Ugbowo Campus in ArcGIS-ArcScene. (NOTE: Animation video web link available here: Click *http://youtu.be/ZuNTeYj0kuk*).

3.5 Demonstration of 3D cartographic animation of the mapped areas in a geo visualization environment

Plate 3 and figure 11 show the photograph and the 3D simulated textural view of the auditorium respectively. Figure 12 shows a snap shot of the simulated navigation animation which is available on the World Wide Web - online (see http://youtu.be/ZuNTeYj0kuk) for perspective view.

Plate 3: Façade photo view of auditorium

Figure 11: 3D Cartographic Texture Map rendition of the auditorium and environ

IV. CONCLUSION

In this study, we demonstrated the capability of ArcGIS (ArcMap and ArcScene modeling tools) in the generation, integration and geovisualization of geospatial data generated from high resolution image and height information from GPS and SRTM in both 2D and 3D animated cartographic models. The study also demonstrates the mapping capabilities of the facility mapping system which makes possible multiple ways of generating focused maps from a single and consistent database as we were able to migrate from ArcMap to ArcScene GIS environment yet using the same centralized database. From the 3D as-built model, spatial information on each building (name, number of floor, height, use and spatial references) are obtained. From flight simulation, the 3D geovisualization of different perspective views of the campus revealed the huge beauty and spatial organisation hitherto unavailable in a traditional 2D map. The study is recommended for the implementation of a campus-wide efficient sustainable spatial planning and electronic street guide. Based on the findings from this study, built environment administrators, planners, geographers, and in particular campus authorities, should be able to provide useful information on facility access, use and resource allocations as well as infrastructure maintenance aimed at administrative excellence. The National University Commission (NUC) should adopt the study model for all Nigerian Universities so as to have a 'click-of-the-button' digital reach and view of University's infrastructural landuse.

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