A 3D Visualization of Transportation Corridor: An Effective Tool in Pre-Analysis of Engineering Project

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Abstract
The development of any infrastructure must go through the design, methodology, materials acquisition and the construction. After the completion of any project, external factors always cause unanticipated future complications such as building or dam collapse. Therefore, one efficient way of overcoming these challenges is to carry out a 3D modelling of the proposed infrastructure and its environs at the design stage so as to compare it with its future state. However, no or little information is available on 3D paper modelling while 3D modelling of structures in a digital space before actual construction in Nigeria especially for transportation corridors has not been reported. This paper presents a demonstration of 3D visualization of a transportation corridor as an effective tool in pre-analysis of engineering project. In this work, an existing infrastructure, part of Ikorodu Road (from Maryland Bus stop to Fadeyi Bus stop), was empirically modelled in three dimensions (3D) to serve as a baseline for monitoring the road infrastructure and human activities along this corridor. The geometry of the road was extracted from an existing satellite image; spatial information on the corridor infrastructure was obtained from the field, while the modelling was carried out in different software environments. Results showed a realistic representation of the existing road corridor infrastructure. The transportation corridor, the infrastructure available and the adjoining land-uses were mapped in 3D (X, Y, Z coordinates).

Keywords: Coordinates*, Extrusion, Modelling, Transport, Visualization.*

1.0 INTRODUCTION

At the core of modelling and virtual reality is the important notion that models are approximations for the real/physical world. Modelling and virtual reality serve as tools that expand the ability to analyse and communicate new research or findings (Sokolowski and Banks, 2009).

The 3D Modelling is one of the greatest important and latest developments in the world of science that involves the method of development of 3D structures using different mathematical processes with the help of curves and lines. 3D modelling is being widely used especially across the field of science and mainly performed using a number of software available online or designed according to the requirement. Using the 3D rendering or the computer simulations, the 3D image that may be visualized on computer screen or can be printed to visualize physically, which is known as a 3D Model (Quimnin, 2016) can be created.

The ability to visualize spatial data has led to further studies in transportation engineering that combines the power of 3D modeling and Geospatial Information Systems (GIS). Transportation visualization has transformed from paper maps to 3D and 4D using scalable computing environments, enabling modeling and simulation outputs to depict “what-if” scenarios (Pramod, 2002).

However, in Nigeria very little is being done in adoption of 3D modeling for proposed/new roads projects. Even for new roads being constructed, government agencies in charge of such roads are often interested in repairs of dilapidated roads shortly after construction instead of putting in adequate measures, such as 3D modelling, to reduce this fund draining pattern. An example is the recent removal of roundabouts on the Lekki-Epe axis in Lagos shortly after construction. This “build then fix it” way of handling engineering projects is resulting in wastage of funds, time and most importantly, life. It is believed that with the adoption of 3D space modelling, and not just physical 3D paper modelling, to engineering projects such as roads, as is done in advanced economy, a lot of *what-if* scenarios could be tested, which would enable the engineers to identify and fix challenges that may arise in future after construction.

This research develops a 3D visualization of a segment of Ikorodu Road. However, it does not cover simulation of vehicle flows. Data on the transportation corridor were collected from both primary and secondary sources; the 3D visualization was carried out basically using Sketch up software; while others components, such as vehicles and street lights, were added to make the 3D model realistic i.e. as a semblance of the existing transportation corridor.

1.1 **Study Area**

Ikorodu road is a main expressway connecting the Lagos Mainland to Ikorodu Town. The road is designated as an A1 Highway for its 24.5 km length. For most of the Lagos portion, it is a three-lane expressway with two frontage roads (called service roads) parallel to the expressway. The expressway crosses other major expressways such as Apapa-Oworonshoki Expressway and Lagos-Ibadan Expressway. The expressways also host many of the Lagos Metropolitan Area Transport Authority's Bus Rapid Transit (BRT) stops and construction more BRT stops on the road towards Ikorodu are ongoing.

The portion of Ikorodu Road (**Figure 1**) used for this study is the roadway that extends from Maryland Bus stop to Fadeyi Bus stop. The length of this segment of the road is about 4.4 Km. There are seven (7) bus stops between Maryland and Fadeyi Bus stops namely: Maryland - Idiroko – Anthony - Obanikoro - Palmgroove - Onipanu - Fadeyi. The land use pattern in this area is a mixture of commercial and residential land uses.

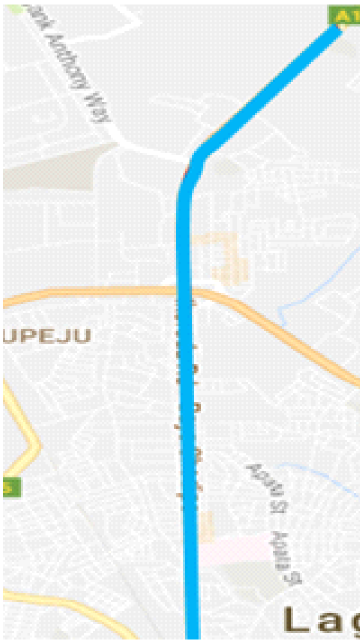

Figure 1: Fadeyi to Maryland Bus stops highlighted in blue (Google map, saved 2016).

1.1 Modeling

A model is a demonstration of an idea, an object or even a process or a system using mathematical, optical, mechanical or numerical (measurements) means. Models guide research in their simplified illustrations of an imagined reality that enable predictions to be developed and tested by experiment (Ipurangi, saved 2016).

3D modeling and visualization can be used for transportation corridor projects. The purpose of developing 3D models for transportation corridor projects is for all involved parties to more easily and intuitively visualize the project and the environment. Design alternatives can be observed and evaluated and changes can be made before construction takes place. With the introduction of 3D, 4-dimensional (4D), virtual reality, 3D simulation and visualization tools, facilities and systems do not have to be installed or built to determine their impact. They can be meticulously visualized, reviewed, tested, and improved at much earlier conceptual stages, before millions of dollars (naira) are spent, even on design (Dewar *et al.,* 2000).

There are mainly three types of 3D Computer Aided Design models. Wire frame is one of them and it is the most abstract and least realistic. Other types of 3D CAD models are surface and solid (Indovance, 2016; CADDIT.Net, 2016. Depending on the different types of shapes and techniques that is to be used for the imaging, rational B-spline modeling, primitive modeling and polygonal modeling can be adopted (Quimnin, 2016).

The benefits of 3D space modeling than physical 3D paper modeling include: faster product design (roughly 45% faster on average); further effective communication with suppliers/customers; the ability to test the stress factors and tolerances of a building or product before commencing building thus saving time, money and potentially disastrous consequences. Other benefits include: ability to depict reality for design proposals or reviews such as complicated concepts and convey complex inter-relationships, which are difficult to visualize; more effective internal design reviews; Generation of virtual prototypes allows non-CAD people to participate in the process; and so on (CADProfessor, 2009).

1.1.1 Transportation Corridor

A transportation corridor is simply a pathway for a particular mode of transportation. It includes built pathways as well as designated pathways, which involve no construction at all (Phorio, 2011). A dysfunctional transportation corridor will automatically make for an in-effective transportation system in all aspects.

There are various types of transportation corridor, but this study focused on only road transportation corridor. There are different lanes on the road corridor. They include: Bus lane and lane (Traffic signs, 2010; DOI UK, 2016). On a road corridor, there are different components that make up a road (**Figure 2**) which include: Right of Way, Formation Width, Road Margins, Width of pavement or carriage way, Parking Lane, Frontage Roads, Drive Way, Cycle Track, Footpath, Guard Rails, Shoulder**,** Side Slopes and Kerbs (Ottawa.ca, 2015).

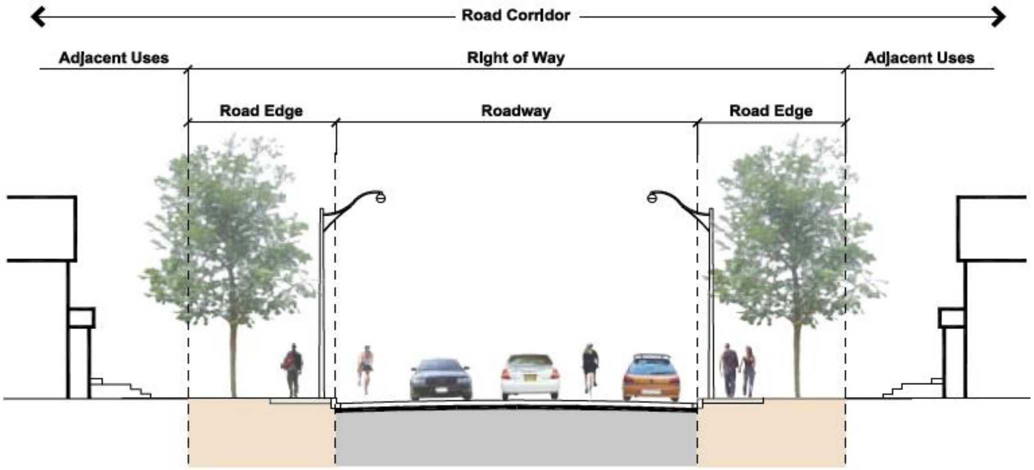

Figure 2: Components of a road (Ottawa.ca, 2015)

There have been growing interests in applying visualization technology for transportation purposes in past years such as: New York Department of Transportation (NYDOT) which was involved in an important urban corridor of approximately 4 km long, contains significant pedestrian hazards, including several school zones (Landphair and Larsen, 1996); 4D Drive-Through Visualization for I-280 by New Jersey Department of Transportation (NJDOT) (Consolazio, 1998); The Urban Simulator project (Jepson *et al.,* 1995) that was developed at the University of California at Los Angeles (UCLA) integrates GIS and Computer Aided Design (CAD) with visual simulation to facilitate modelling, display, and evaluation of proposed alternatives.

2.0 METHODOLOGY

The following steps and the flowchart (**Figure 3**) for the methodology adopted are stated below.

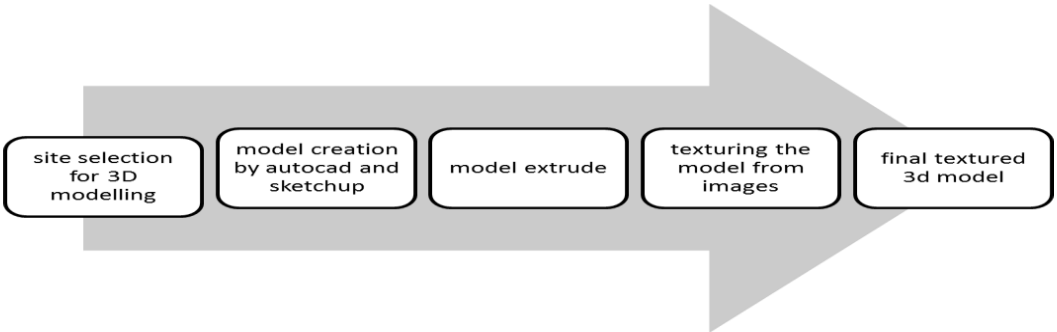

Figure 3: Flow Chart of the Methodology for the 3D Modelling.

The software used for the study include: Windows 7 (Operating system), AutoCAD, Sketchup, Google Earth, Microsoft word 2010 and Sketch (Screen capture software); while the hardware used include: Camera, High Graphics Computer and Internet modem.

2.1 Site Selection for the 3D Modelling

The site chosen for the 3D modelling is the road corridor along Ikorodu Road, from Maryland Bus stop to Fadeyi Bus stop. The length of the road selection is 4.4 km.

Data Collection: The data collection process is divided into two: Primary and Secondary Data.

Primary Data: These include coordinates of bus stops and pedestrian bridges (**Table 1**), and photographs of some facilities along the road segment (**Figures 4a and 4b**).

Secondary Data: These also include a cropped image of Maryland to Fadeyi Road Corridor from Google Earth (**Figure 5a**) and a Digital Road Network Map of Lagos State obtained from Lagos State Ministry of Physical Planning and Urban Development (**Figure 5b**).

Figure 4.1a: Fadeyi BRT Bus stop facility and some commercial activities (Houses and Shopping complex) behind the Bus stop

Figure 4.1b: Pedestrian Bridge at Fadeyi Bus Stop

2.2 Model Creation in AutoCAD and Sketch up:

After the acquisition of the study area data, the satellite imagery was cropped out and vectorised in AutoCAD (**Figure 5a**) and then imported into Sketch up for modelling.

Figure 5a: Satellite Image of Maryland to Fadeyi Road Corridor highlighted in blue and red (Google Earth, saved 2016)

Figure 5b: Road Network Map (Ministry of Physical Planning and Urban Development, 2010)

The model building was based on the principle of 3D modelling. All the objects along the road corridor were defined on a three-axis system [i.e. X-axis, Y-axis and the Z-axis] (**Figure 6**). Though the Z-axis does not totally define the 3D object, it is the essential difference between 2D and 3D objects. The Z coordinate, in this work, represents the heights: of the kerbs, pedestrian bridges, bus stops, electric poles and so on (Lifewire, 2016).

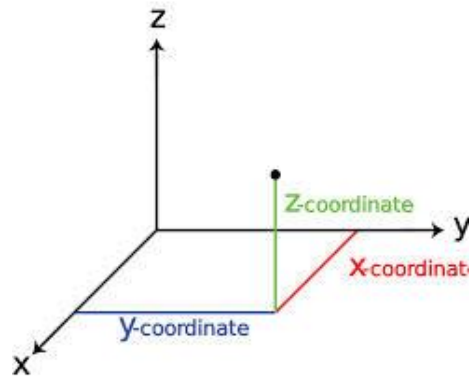

Figure 6: A representation of a three-dimensional Cartesian coordinate system with the *x*-axis pointing towards the observer

2.3 Clean-up of Cad File:

The imported vectors were cleaned up in Sketchup. This involves deleting unwanted geometry, adding missing geometry and editing disjointed geometry.

2.4 Face Covering

After the clean-up, the roads and spaces on the map were covered with *faces* (these are surfaces in Sketchup). A *face* is defined by the edges that surround it, and those edges have to be on the same flat plane. To make a closed shape, at least three straight lines are needed. Therefore, *faces* must have at least three sides. Without *faces* the models cannot be drawn out. The *faces* were drawn by closing up spaces in the geometry (**Figure 7**).

2.5 Extrusion

After creating *faces*, extrusion was carried out. Extrusion involves pulling out *faces* on the model so as to add volume/height to the model. This means adding realism to the model. The buildings, road pavements, pedestrian bridges, bus stops, electric poles and others were extruded in this work (**Figure 8**).

2.6 Texturing

After extrusion, texturing was also carried out on all the objects. Texturing involves matching a texture or photo or colour to all or certain *faces* in the model (**Figure 9**).

2.7 Import of Components

After texturing, *components* were then imported by downloading them from Trimble 3dwarehouse (2016). *Components* are modelled objects that are created externally (i.e. in another software environment) and can be imported to complete modelling. The imported *components* are to make the project more graphical and understandable by viewers so that they can relate with the model (**Figures 10 - 14**).

3.0 RESULTS AND DISCUSSION

Results obtained are shown in **Tables 1-2** and **Figures 8-14.**

3.1 Results

Table 1: Spatial Locations of Bus Stops and the Pedestrian Bridges

S/N	Name of Location	Bus Stops				Pedestrian Crossing.			
		LEC (m)	LNC (m)	REC (m)	RNC (m)	LEC (m)	LNC (m)	REC (m)	RNC (m)
1	Maryland	540599.75	726445.27	540641.01	726309.09	Nil.	Nil.	Nil.	Nil.
2	Idi-Iroko	540520.77	725857.52	540570.27	725576.44	540520.99	725865.37	540574.74	725863.86
3	Anthony	540532.29	725141.19	540574.33	724983.75	540539.12	724871.08	540595.19	724873.88
4	Obanikoro	540561.54	723625.52	540632.56	723625.78	540569.65	723632.53	540620.25	723630.31
5	Palmgrove	540580.92	723084.96	540617.75	723091.01	540573.84	723076.60	540615.59	723075.85
6	Onipanu	540593.63	722539.75	540638.48	722134.09	540598.74	722186.32	540637.99	722186.45
7	Fadeyi	540616.78	721559.48	540662.93	721547.48	540618.43	721551.24	540651.89	721551.97

* LEC- Left Easting Coordinates; LNC- Left Northing Coordinates; REC- Right Easting Coordinates; RNC- Right Northing Coordinates

For the graphical models:

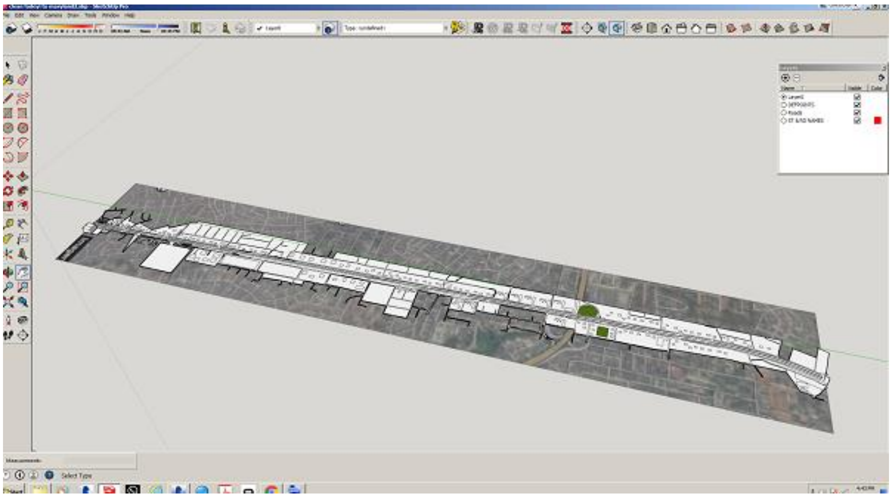

Figure 7: Corridor Satellite imagery covered with Faces

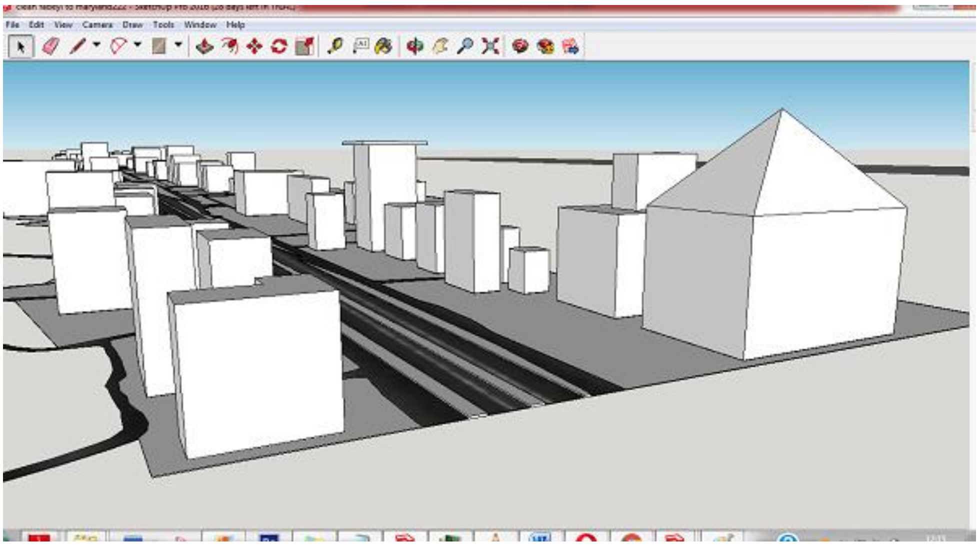

Figure 8: Modelling and Extrusion of Buildings

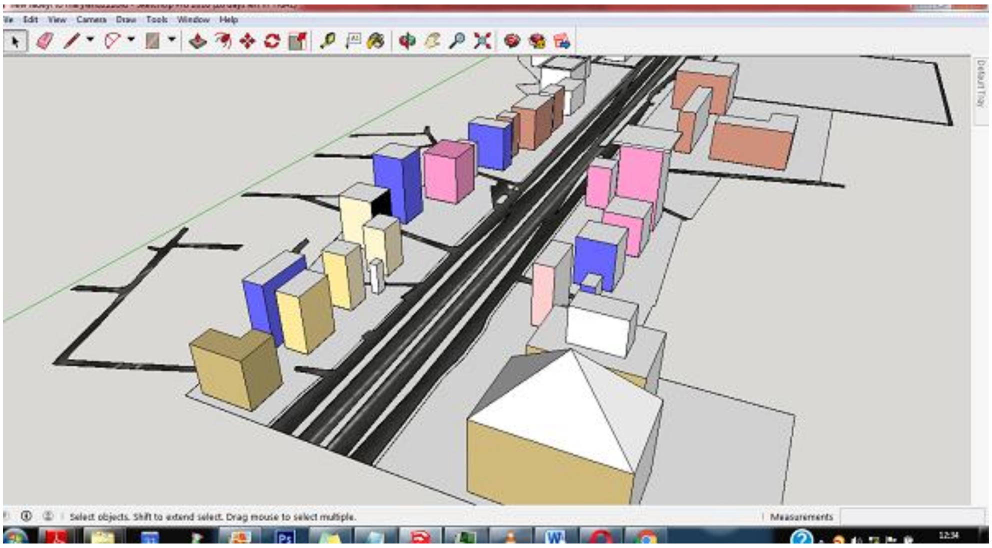

Figure 9: Painting of Blocks of adjoining Houses

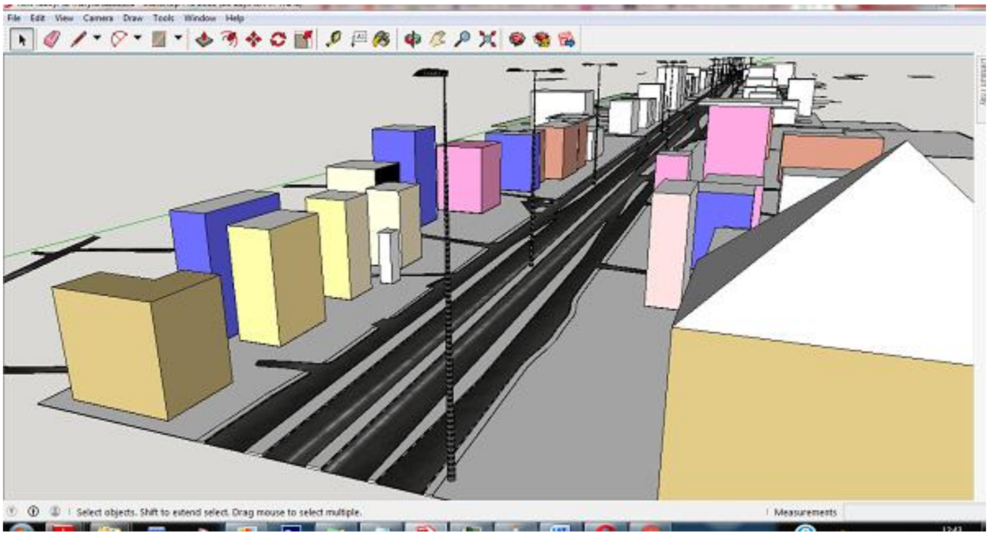

Figure 10: Streetlights imported into the Model

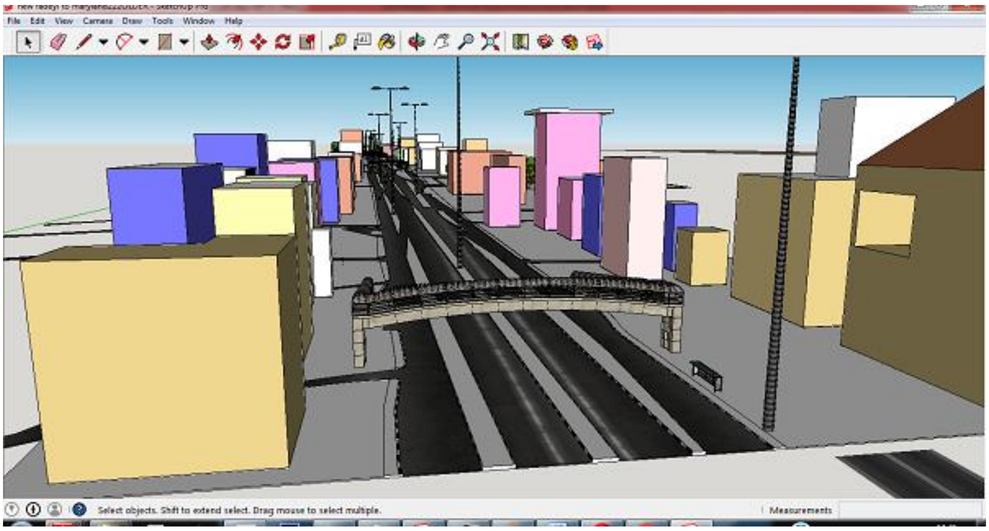

Figure 11: Pedestrian Bridges and Bus stops in the Model

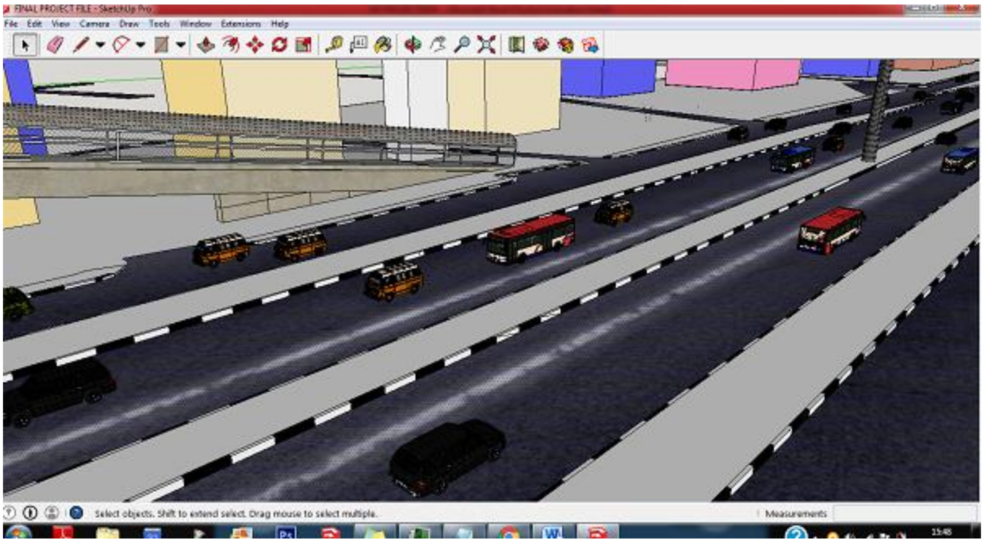

Figure 12: Modelled typical Vehicles plying the Road Corridor

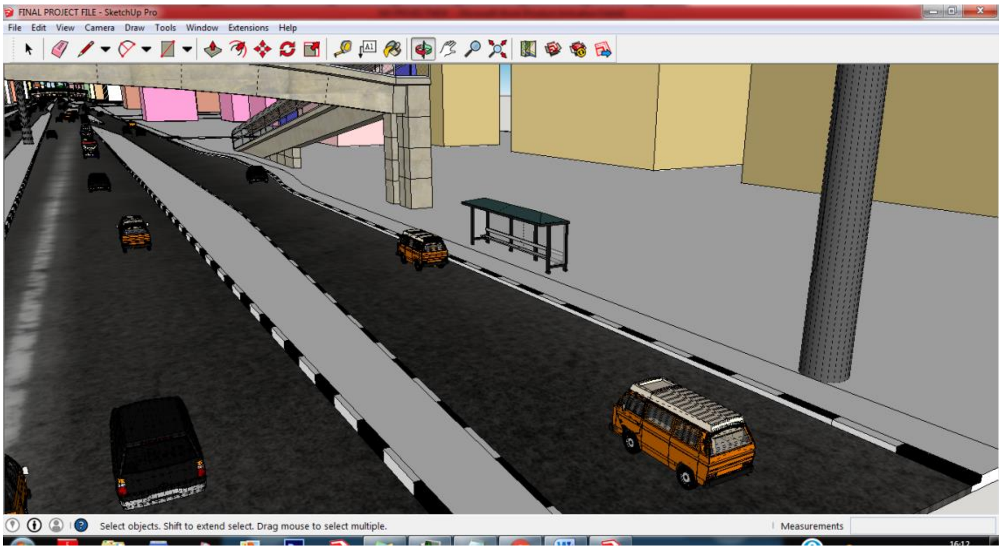

Figure 13: BRT Bus Stop Shed and Right-of-Way in the Model

Figure 14: Road Intersection along the Corridor on Ikorodu Road

3.2 Discussion

A model is a miniature representation of the reality. Model scale is always smaller than ground scale. Therefore, comparing the dimensions and the relative spatial location of infrastructures on the model with their corresponding ground features, the model components are true representation of the reality i.e. the road corridor.

The extrusion process depicted the heights of various physical features mapped such as buildings, road pavements and pedestrian bridges. The extrusion (**Figures 8 and 11**) is very crucial in 3D modeling, especially for road corridors, as it assists in determining the height of heavy vehicles that can pass under the bridges (flyover and pedestrian bridges).

Figures 10-14 convey complex engineering inter-relationships between the modeled features. For examples, the standard/approved distance between bus stops and pedestrian bridges, the intervals between bus stops, the intervals between street lights, lane intersections, just to mention but a few can be viewed before construction. Similarly, the direction of vehicular flow, width of each lane, number of lanes on each side, divider type and road layout **(Figure 12)** are all depicted for visual acuity. All these will enable experts to gain applicable understanding of the system, the road corridor, being modeled.

Finally, with the 3D modeling created before construction, the need for identifying pedestrian hazards spots such as new school zones, accident black spots, encroachments into the Right of Way (ROW), bus stop relocation (**Figure 13**), lane expansion among other roadway demands can easily be determined and mapped on the model created.

4.0 CONCLUSION

3D Modeling serves as a risk minimisation strategy for clients with large, technically challenging projects (Liberty Industrial, 2016). It assumes the role of communication facilitator and has proven to be very useful in conveying information regarding the design.

This work mapped the locations (i.e. X, Y, Z coordinates) of the transportation corridor, the infrastructures available and the adjoining land-uses in 3D. It has brought into place the need for developing 3D models for transportation corridor projects in order to allow all involved parties to easily and intuitively visualize the project.

3D modelling is still relatively new in Nigeria and needs to be embraced because the world at large is gearing towards newer and easier forms of doing things using modern day technology. Nigeria needs to embrace this new trend.

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