



GEOMETRIC DESIGN OF EWOI ROAD FROM OTUOKE TO EWOI COMMUNITY

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ABSTRACT

Roads' geometric design is crucial for the safety, efficiency, and sustainability of transportation systems, especially in rural and developing regions. This research examines the geometric design of Ewoi Road, an essential connector between Otuoke and the Ewoi community, with the goal of tackling transportation issues that hinder regional socio-economic development. The project stresses the establishment of a road infrastructure that improves accessibility, eases the transport of people and goods, and promotes regional growth. The study starts with a thorough evaluation of the current road conditions, encompassing traffic flow, terrain features, and environmental effects. To ensure an informed design process, field surveys, geotechnical investigations, and traffic volume studies are carried out to gather the required data. Essential geometric design parameters, including horizontal and vertical alignments, cross-sectional elements, sight distances, and gradients, are established in accordance with national and international standards to guarantee safety, efficiency, and durability. Through innovative design solutions, challenges like inadequate road width, poor drainage, and steep gradients are identified and tackled. The proposed design includes drainage systems to alleviate flooding, optimized alignments to lower construction costs, and

measures for accommodating future traffic growth. Moreover, the design incorporates sustainable practices such as using eco-friendly materials and implementing erosion control measures. This study has resulted in a thorough geometric design that caters to the transportation needs of the Otuoke-Ewoi corridor, while also fostering environmental sustainability and economic development. The proposed road design is anticipated to greatly enhance connectivity, decrease travel times, and improve residents' quality of life, serving as a model for similar infrastructure initiatives in rural and peri-urban regions. This research emphasizes how crucial it is to design roads strategically for regional change and sustainable development.

Keywords: Geometric design, road infrastructure, transportation, Ewoi Road, traffic flow, drainage, sustainability, eco-friendly materials, erosion control, regional growth, connectivity, travel time, quality of life, strategic planning.

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1. INTRODUCTION

Since gaining independence, Nigeria has experienced swift economic and societal progress, which has led to a greater demand for intercity travel and a need for safe and quality roadways.

Developing a superior road network boosts a nation's economic productivity by cutting down travel times and expenses, ultimately making the area more economically appealing. To accomplish this, both the Nigerian authorities and the general populace ensure that the roads are geometrically designed before they are built. The geometric design of highways is a focus within Civil Engineering that addresses the measurements and arrangement of the road's physical elements according to standards and limitations to best meet the needs of users and vehicles. The primary goals are to enhance efficiency and safety while reducing costs and minimizing harm to the environment. Additionally, geometric design impacts a new fifth goal known as livability, which emphasizes creating roads that support broader community objectives, such as providing access to jobs, educational institutions, businesses, and housing.

The Role of FHWA Programs in Livability: State of Practice Summary Federal Highway Administration Retrieved April (2012).

According to Charles et al. (2010), the Ewoi road is situated in the town of Otuoque within the Ogbia local government area of Bayelsa State. Located in the coastal area of Nigeria's southern region, specifically within the Niger Delta, Bayelsa State has witnessed changes over the past decade. Once merely a forested path, it now takes approximately 45 minutes to walk from the Otuoque T-junction to Ewoi. Ten years prior, the road construction involved manual labor using shovels for digging and backfilling. Clearances for the road were typically done manually with assistance from the Community Development Committee, the local Councilor, and the local government chairman. The road underwent a dualization process in 2015 during the previous president's term, executed by Akon Nigeria Limited.

2.1 MATERIALS

2.1.1 INTRODUCTION

The approach utilized in this project is split into two parts. The first part pertains to field activities, which involve route surveying, including reconnaissance, preliminary, and location surveys. The second part relates to office tasks, focusing on the design components which include the road's horizontal alignment and cross sections employing civil 3D AutoCAD 2018.

SECTION 1: FIELD WORK

2.2 Route Assessment

This assessment offers a design or map outlining the layout, specifics, profile, and cross-sectional leveling that illustrates the characteristics of the terrain across a specified area. This serves to aid in the identification, planning, and construction of a route network. As previously mentioned, this includes:

1. Initial survey
2. Basic survey
3. Site survey

2.2.1. Initial Survey

The initial survey marks the initial phase of selecting a pathway, entailing an examination of a broad region from one terminus of the intended route to the other, ensuring a thorough and comprehensive analysis of all viable locations for the route.

Typically, route selection incorporates aerial photographs, satellite pictures, and ground assessments, alongside evaluating current plans and maps. The goal of this survey is to determine if access routes to the community are practical or workable, as well as to pinpoint more favorable routes or locations.

From the foundational map, it was concluded that the path from Otuoke Ewoi Junction to Ewoi community represents the most optimal option. The findings from this survey facilitate the execution of the basic survey.

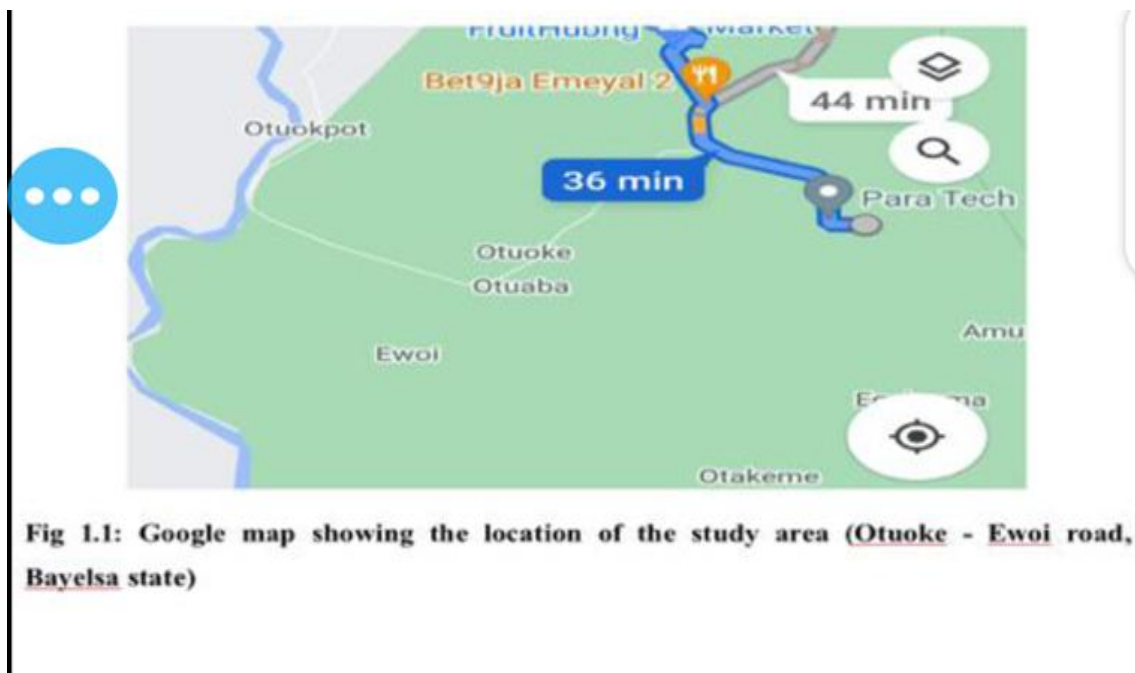


Fig 1.1: Google map showing the location of the study area (Otuoke - Ewoi road, Bayelsa state)

Fig. 1.1: Google map showing the location of the study area (Otuoke – Ewoi) road, Bayelsa State.

2.2.2. Initial Survey

This section involves an in-depth examination of the selected route based on data gathered from a reconnaissance survey to finalize the positioning of the centerline. It entails gathering sufficient route information regarding vertical and horizontal alignments, the terrain, and the cross-section of the roadway to aid in the design or construction phase, enabling the creation of precise project plans, specifications, and cost estimates.

The process is conducted in a manner that aims to deliver optimal results, ensuring that the final centerline is established in the field with minimal changes, except for slight adjustments that might be needed in specific instances.

This operation is performed through traversing to capture levels and plot the findings.

2.2.3. Final Positioning Survey

This stage illustrates the comprehensive arrangement of the chosen routes. During this phase, both the final horizontal and vertical alignments are confirmed, as well as the ultimate locations of structures and drainage systems. The typical approach begins by marking out the points of intersection (PI) along the straight segments of the highway, followed by the integration of an appropriate horizontal curve between these points. This method generally requires trial and error until the designer is satisfied that the alignment provides the best solution, factoring in both engineering and visual appeal.

2.2.4. Traversing

Traversing is a surveying technique used to assess the characteristics of a route by considering the elevation and distances between various points through angle and distance measurements of connected segments. This process facilitates the determination of the road's horizontal and vertical alignment and topography and is executed utilizing Total Station Equipment, which includes tools such as measuring tapes and chains. The locations from which measurements are taken during traversing are referred to as traverse stations, and the distance between any two points of measurement is known as a traverse line.



Figure 2.1 – Process of Traversing using leveling instrument

Total Station

Total station is equipment for carrying out a traverse. During the survey the condition of the road with respect to the following parameters were observed.

- Horizontal alignment
- Super Elevation
- Design speed
- Sight distances



Figure 2.2 – Data Collection using Total Station

SECTION 2: OFFICE WORK.

2.3 Layout

In this section, we examine the various elements involved in road layout and the method utilized to create a comprehensive road design using the data collected during fieldwork.

The software employed to generate the complete road design was AutoCAD Civil 3D (2018 edition).

2.4 Geometric Design of The Road

Once the profile or longitudinal section is plotted,

it is essential to establish a level surface for a smooth ride, referred to as the grade line.

This line is chosen based on several factors, including minimizing earthwork cut and fill, managing the cut and fill effectively, and maintaining slopes within permitted limits.

Therefore, it is important to take into account the fundamental design aspects, which include:

2.4.1. Road Categorization

Nigeria has various road categories, and the specific road under discussion qualifies as a two-lane highway.

2.4.2. Two-Lane Highway

A two-lane highway is a type of expressway that features one lane in each direction. These roads are generally broader than private roads, and there may or may not be a barrier in the center separating the two lanes. The carriageway width is 7.5 meters for a single lane and 7.0 meters for a two-lane setup without raised curbs, while the width becomes 7.5 meters for two lanes with raised curbs.

2.4.3. Sectioning

Sectioning involves identifying the changes in elevation both along and perpendicular to the centerline.

There are two primary types of sectioning that we focus on.

2.4.4. Longitudinal Section or Profile

The longitudinal section or profile illustrates the elevation of the ground along the proposed road's centerline. This is critical for establishing a well-designed road. The centerline is established using total stations at regular intervals of 25 meters, after which the levelling procedure begins along this line.

Levelling initiates from a fixed benchmark, and measurements are recorded at the top and bottom of pegs set at the aforementioned intervals along the centerline, extending to areas where there are abrupt elevation changes and at the start or end of curves.

2.4.5. Cross Section

A cross section provides an end view of a particular section perpendicular to the centerline. This is crucial for understanding the area's topography, which is necessary for calculating the volume of earth to be excavated or added during construction.

2.4.6. Horizontal Alignment

Horizontal alignment consists of the straight stretches of road connected by appropriate curves, facilitating a transition between two straight sections (tangents) of the roadway. Factors such as driver constraints, vehicle specifications, and costs influence the horizontal alignment. In designing horizontal alignment, considerations include:

- Design speed
- Super elevation
- Curve radius
- Side friction

These factors were examined in detail in chapter 2, but I will provide a brief further emphasis on them.

The formulas applied for designing the horizontal alignment are as follows:

The formulas that used in the calculation of horizontal curves are interpreted below: -

The deflection Angle, Delta (A) is given by:

The deflection Angle, Delta (A) is given by:

$D =$

Length of a circular curve is given by:

$L =$

Where D is the degree of curvature and R is the radius of curvature in feet.

Simple Circular Curve

A simple circular curve is a curve connecting two intersecting straight having a constant radius throughout the curve. This type of curve is tangential to the straight at the joining sides.

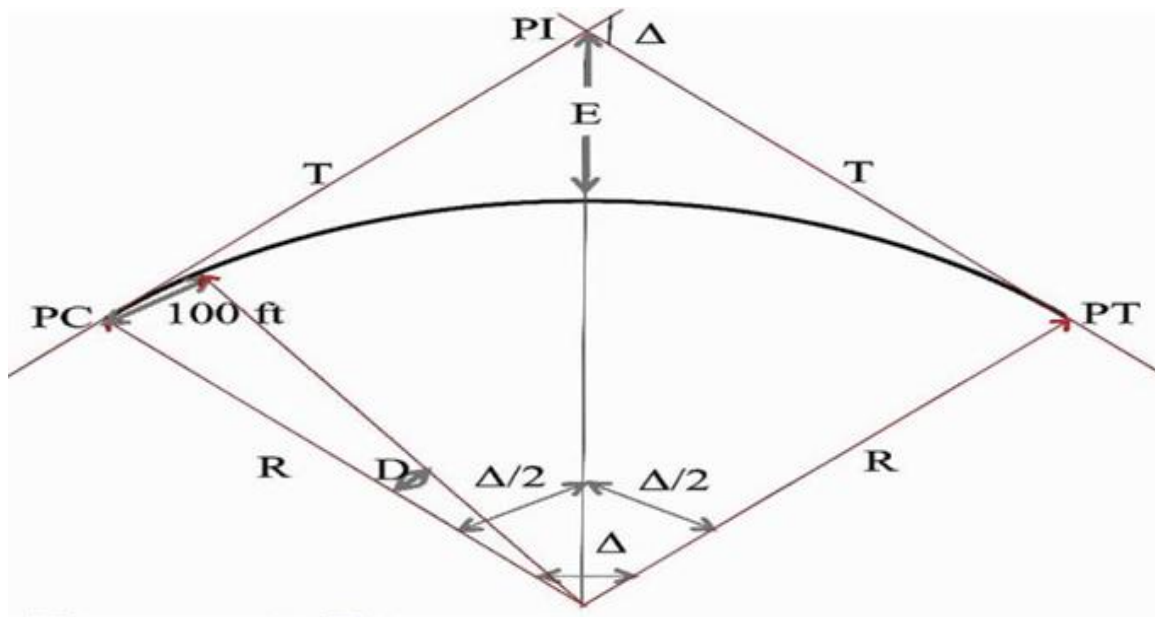


Figure 2.3: Element of Simple Circular Curve

T= Tangent

L = Length of curve

LC = Length of chord

D =Degree of curvature,

E = External (Secant) Distance

M = Mid-ordinate

Knowing the chainage of PI

Chainage of PC= chainage of PI- T

Chainage of PT = chainage of PC + LC

2.5 Design Velocity

The manual specifies that the recommended design velocity in Nigeria is 97km/hr for highways with restricted access. Nevertheless, the road in question is classified as a rural road. The design velocity for rural routes should be as elevated as feasible to achieve the best possible safety and operational effectiveness. Consequently, a design speed of 100km/hr was selected, taking into account the characteristics of the surrounding area, treating the road as if it were a highway.

2.6 Traffic Information

These are fundamental design components taken into account for ensuring a safe and seamless driving experience for vehicles.

3.1 RESULT AND DISCUSSION

3.2 Geometrical Design

The arrangement of the proposed roadway was crafted in accordance with the standards established by the federal ministry of works and housing, specifically detailed in the first section of the highway design manual, and was designed using AutoCAD Civil 3D 2012 software.

3.3 Design Speed

Per the manual, the advisable design speed for limited access highways in Nigeria is 97 km/hr. Consequently, for this project, we have determined the design speed to be 100 km/hr, taking into account the features of the region, thereby ensuring the road meets highway standards.

3.4 Sight Distance

A sight distance of 1.07m was set to enable drivers to have a clear view ahead, thereby fostering safe and efficient driving on the highway. Sight distance is defined as the length of the road visible to the driver at eye level. This measurement also dictates the required distance for building fences and other barriers to be set back from horizontal curves.

3.4.1 Stopping Sight Distance

Stopping sight distance includes two parts: the span a vehicle covers from the moment a driver notices an object necessitating a stop until the brakes are fully applied, in addition to the distance needed for the vehicle to halt completely after braking has started. These distances are termed brake reaction distance and braking distance, respectively. According to AASHTO, “for a roadway with a speed of 100 km/hr, a sight distance of 185m is required,” and thus, we have incorporated a stopping sight distance of 185m into our design.

3.4.2 Passing Sight Distance

The proposed roadway features a single lane where vehicles typically move at reduced speeds. To ensure proper design, the passing sight distance must be computed according to the length required for standard passing actions, allowing the driver to verify the absence of obstructive vehicles ahead before beginning the action. For a road

intended for speeds of 100 km/hr, the necessary passing sight distance is 670 meters, which includes the distance for the initial action, lane usage, required clearance, and consideration of oncoming vehicles.

3.5 Arrangement

The configuration of a road pertains to the position of the centerline when observed from a bird's-eye view.

This centerline is determined before construction commences. Aspects such as construction costs, maintenance, safety, and travel smoothness are all impacted by this layout. Therefore, selecting a road design is crucial and should be done with care.

There are two types of arrangements;

1. Lateral arrangement
2. Vertical arrangement

3.5.1 Horizontal alignment

The following is a sample among the horizontal curves that are design. In the design of horizontal curve, the basic parameters and the governing equations are presented below:

$$TL = R \tan \Delta/2$$

$$LC = 2R \sin \Delta/2$$

$$CL = \Delta/360 \times 2\pi R$$

Where Δ = deflection angle,

R = radius,

TL= tangent length,

LC= length of chord,

CL=curve length

Table 3.1: Horizontal Curves Computation Results

CURVES	Angle of Curve	R(m)	TL(m)	LC(m)	CL(m)
Curve1	09° 36' 22''	750.000	68.04	125.725	125.872
Curve2	18° 06' 35''	900.000	143.431	283.286	284.469
Curve3	12° 11' 58''	450.000	48.089	95.634	95.815
Curve4	105° 57' 24''	120.000	159.120	191.616	221.915

3.5.2 VERTICAL DISTANCES

Table 3.2: Vertical Distances

Chainage	Existing Ground Level	Finished Level
0+000	20.63	20.700
0+025	19.96	20.771
0+050	20.13	20.843
0+075	20.22	20.914
0+100	20.31	20.986
0+125	20.26	21.057
0+150	20.21	21.129
0+175	20.20	21.200
0+200	20.15	21.271
0+225	20.11	21.343
0+250	20.09	21.414

3.6 EARTH WORK VOLUME

The value of earthwork materials which described the cut and fill for the proposed site of the roadway was calculated using the formula;

$$V = L (\underline{A_1 + A_2})$$

Where;

L is the length between two stations

A₁ is the area at the first station

A₂ is the area at the second station

Sample calculation;

Consider between stations CH 0+025 to CH 0+050, CH 0+075 to CH 0+100, CH 0+125 to CH 0+150

CH 0+025 to CH 0+050

$$A_1 = 6.85\text{m}^2$$

$$A_2 = 15.34\text{m}^2$$

$$L = 25\text{m}$$

$$\text{Therefore, } V = 25 \left(= 25 \left(V = 25 \times 11.095, V = 277.30\text{m}^3 \right. \right.$$

CH 0+075 to CH 0+100

$$A_1 = 24.37$$

$$A_2 = 32.15$$

$$L = 25\text{m}$$

$$\text{Therefore, } V = 25 = 25 \quad V = 25 \times 28.26, V = 706.54\text{m}^3$$

In a similar way, the other volumes of cut and fill for all the stations was calculated using AutoCAD Civil 3D 2012, and is attached in appendix II.

3.7 CROSS SECTION

The cross sections for every chainage of the road were created based on the vertical profile of the road, and the table for these cross sections can be found in appendix IV. The roadway's cross section provides the necessary information for calculating the volume of earthwork.

4.1 CONCLUSION

The roadway was crafted following the suggestions from the Federal Ministry of Works' highway design manual.

The geometric layout of the road, which encompasses both horizontal and vertical alignments as well as its cross-sections, was intended to ensure accurate earthwork and provide appropriate horizontal and vertical curves to facilitate smooth directional changes.

A design velocity of 100 kilometers per hour was established, with a stopping sight distance of 185 meters and a passing sight distance of 670 meters.

The entire roadway was measured at intervals of 25 meters, with a total length of 3 kilometers and a width of 6 meters. To aid in vehicle transitions, four horizontal curves were incorporated into the design. The horizontal and vertical distances were measured from 0.000 to 3+000.

The total volume of earthwork excavation was calculated to be 13,718 cubic meters, while the cumulative field volume was found to be 335.36 cubic meters, as computed using software, detailed further in Chapter Four (IV).

4.2 RECOMMENDATION

Based on the previous information, the following steps should be undertaken for highway design:

1. Conduct a route survey
2. Utilize the obtained measurements to ascertain the current levels for the vertical alignment and the flat profile for the horizontal alignment.
3. Use the elevation data to determine the finished level for the vertical alignment by calculating the cut and fill slopes.
4. Engineers tasked with designing the road network must adhere to the guidelines provided by the Federal Ministry of Works and Housing, specifically the first part of the highway design manual, which focuses on creating efficient and cost-effective road designs.
5. Employ contemporary software tools like MicroStation, AutoTURN, and Carlson Civil, as these can help minimize the number of required curves. Alternatively, AutoCAD Civil 3D tends to yield more curves.

Additionally, reconnaissance surveys can now be facilitated using Google Earth to enhance efficiency and reduce expenses.

4.3. ACKNOWLEDGEMENT

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