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Geometric Alignment of Western Bypass Road, Federal Capital Territory, Abuja, Nigeria

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ABSTRACT

This study, titled "The Geometric Alignment of Western Bypass, Federal Capital Territory, Abuja", focuses on the geometric improvement of the Western Bypass, a critical road in Abuja, Nigeria's Federal Capital Territory (FCT). The study involves creating road alignment, plotting alignment profiles using coordinates (easting and northing), analyzing cross-sections and elevations, and conducting various analyses to select the optimal alignment while adhering to design standards. Geometric Alignment in highway engineering enhances road safety, traffic efficiency, and overall performance. However, manual geometric design is often inconvenient, time-consuming, and prone to costly errors. The Western By-Pass, a bituminous road, has experienced significant deterioration due to constraints such as traffic growth, inadequate geometric features, and environmental conditions. The primary goal of this research is to propose an improved geometric alignment that optimizes safety, efficiency, and comfort while minimizing environmental impact. The study evaluates existing road conditions, assesses traffic volume and speed variations, and proposes geometric improvements such as shoulder widths, lane widths, and horizontal and vertical alignment. The research methodology includes the use of computer-aided design (CAD) software such as AutoCAD Civil 3D, and Blender to ensure precision and efficiency in the design process. The specific objectives of the research include determining the existing highway capacity, speed variations, and traffic volume, and proposing a geometric alignment that adheres to national design standards. The existing road spans 5.8km and has a design speed of 68km/h. The study evaluated the roads the roads' horizontal and vertical alignments, cross sections, and other geometric features to ensure smooth directional changes and improved traffic flow. The analysis included calculating cumulative cut volume, filled volume, and net volume to assess the road's current condition and propose necessary improvements. The findings aim to optimize the roads' performance, minimize environmental impact, and ensure more efficient transportation for users.

KEYWORDS: Geometrical Alignment, Highway Design, Speed Variation, Western Bypass, Traffic Efficiency.

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1 | INTRODUCTION

Geometric design is a highway engineering field that deals with the arrangement of physical components of the road by standards and constraints (Gibreel et al, 1999). It is also the arrangement of visible characteristics on a roadway to satisfy the demands of pedestrians and automobiles. The major aim of geometric designs and alignments is to improve efficiency and safety while cutting costs and reducing environmental impact.

The tremendous traffic growth, discomfort, lack of safety, and uneven roadway generally observed on the WESTERN BYPASS road has led to a lot of negative consequences in the form of road accidents and insecurity which is why the call for considerable attention towards the improvement of the road. It has been of great importance to build and improve high-quality roads to accommodate the needs of society and by having a proper road structure, and a geometric design, improvements in the roads can be achieved in various sectors of the road design such as safer intersections, more durable roads and pavements and also, better understanding of vehicle performance (Jafari & Noorzai., 2021).

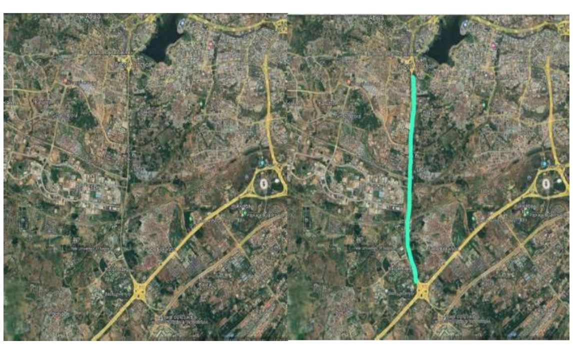

Plate 1: Aerial view of western bypass

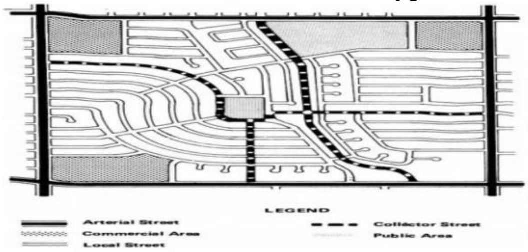

Figure 1: Schematic Illustration of the Functional Classes for a Suburban Road Network. (source, American Association of State Highway and Transportation Officials, 2004.)

2 | MATERIALS AND METHODS

The current methodology is based on a single parameter: traffic congestion. This metric was calculated and interpreted for the study region to determine the severity of the current traffic flow.

Data Collection

The research was carried out at a congested, signalized two-lane, two-way road in Abuja. The survey aims to collect information on road geometry and traffic flows. A metro count device was used for traffic count for 7 days. Road tubes were connected to the metro count device. Collecting traffic data is crucial for infrastructure design related to road pavements and safe routes for active transport.

Geometric Evaluation

Google Earth was used to collect the road measurements & and access the geographical conditions of the proposed path of study.

Processing of the Survey Data

The data acquired using Google Earth was therefore transported into Microsoft Excel using this format; point, northing, easting, zenith, description (PNEZD), and saved as comma delimited.

Optimal Solution

The optimum solution was decided upon based on the Level of Service using Delay and V/C (Volume to Capacity ratio) (HCM 2010).

Design Capacity

Design capacity can be calculated through various methods. The capacity of a two-lane, two-way road is typically calculated using traffic engineering principles. One commonly used method is the Highway Capacity Manual (HCM) method. The HCM provides a formula for determining the capacity (Q) of a two-lane, two-way road based on the following parameters:

$Q=3.0\times L\times(1+0.5\times V/fV)\times K\times f$…Equation (**I**)

Where: Q is the capacity of the two-lane, two-way road (in vehicles per hour).

. L is the number of lanes in one direction
. V is the average speed of vehicles (in miles per hour).
. Vf is the free flow speed of vehicles (in miles per hour).
. K is a lane adjustment factor (1.0 for two-lane highways).
. f is the flow rate as a decimal (flow rate is the actual volume of traffic divided by the theoretical capacity). (Erua J.B et al., 2017)

It is important to note that the actual flow rate (f) is influenced by various factors, including geometric design, and traffic control devices.

To Determine the Speed Variation

The speed variation on a two-lane, two-way road can be influenced by several factors, and there isn't a single formula that universally captures all aspects of speed variation. However, one commonly used concept to understand speed variation is the "98th percentile speed."

The 98th percentile speed is the speed at or below which 98% of drivers are traveling on a road under free-flow conditions (no congestion, good weather, etc.). This speed is often used as a basis for setting speed limits. One formula to estimate the 98th percentile speed is:

V98=A+B× (mean speed−A) ...Equation (**ii**).

• V98 is the 98th percentile speed.
• A is a constant related to the speed of traffic when roads are clear,
• B is a constant related to the sensitivity of drivers to changes in mean speed. These constants are typically determined empirically based on the characteristics of the specific road and its users (Erua et al., 2017)

Peak Hour Factor (PHF)

A measure of the variability of the demand during the peak hour is given as:

$$PHF = \frac{\text{Peak Hour Volume}}{4 \times \text{peak 15 min volume during peak hour}}$$

Equation (**iii**) (Erua J.B et al, 2017)

Design Hourly Volume (DHV)

$$\frac{\text{Peak Hour Volume}}{\text{DHV}} = \text{Peak Hour Factor}$$

…Eqn…(**iv**) (Erua J.B et al., 2017)

3 | RESULTS

A summary of the research findings includes the segment where traffic data was obtained and was surveyed for seven days from 7:00 a.m. to 6:00 p.m. The collected data was presented in tables and graphs to describe the road traffic pattern in the research region. The findings of the field investigations have been analyzed and will be classified as follows:

- Traffic data
- Peak-hour traffic

- Geometric parameters
- Design Volume and Performance

Table 1. Average weekly Traffic (AWT) along the Western by-pass, FCT, Abuja

Time (Hrs.)	Mon	Tue	Wed	Thu	Fri	Sat	Sun
0700-1900	36238	36929	30184	34844	36498	33750	23155
0600-2200	42465	43465	35410	41211	43097	40050	27712
0600 1200	43416	44527	35528	42297	44581	41057	28364
1200-0000	43537	45092	36192	42886	45228	42052	28603

From **Table 1.** above, the peak hour traffic occurs on Friday at 1200 hours with an average weekly traffic of 4522 vehicles.

Table 2. Table Vehicle classification along the western by-pass, FCT, Abuja. Source (FRSC)

Class													
	MC	SV	SVT	TB2	TB3	T4	ART3	ART4	ART5	ART6	BD	DRT	Total
km/h	1	2	3	4	5	6	7	8	9	10	11	12	
16-24	30	280	0	14	3	4	1	0	0	0	0	0	332
24-32	51	1247	5	31	14	13	1	7	5	8	1	4	1387
32-40	107	2978	43	148	52	58	7	17	12	26	11	32	3491
40-48	227	11129	204	650	144	130	14	126	61	152	36	166	13039
48-56	391	32515	434	2152	238	208	25	313	97	299	48	317	37037
56-64	656	54704	491	4546	341	166	48	407	114	412	37	382	62304
64-72	783	57865	412	6443	243	134	61	329	73	351	16	226	66936
72-80	745	43016	292	6139	139	71	53	204	60	177	5	105	51006
80-89	492	22899	135	4238	68	33	31	81	19	77	1	31	28105
89-97	175	9822	61	2169	22	12	21	40	8	29	1	5	12365
97-105	72	3392	27	1025	5	0	7	6	4	5	0	1	4544
97-105	16	1229	5	434	4	1	5	5	0	1	0	0	1700
105-113	4	504	1	212	1	0	0	1	0	0	0	0	723
113-121	1	175	0	85	1	0	0	0	0	0	0	0	262
121-129	0	109	0	62	0	0	0	0	0	0	0	0	171
129-137	1	73	0	33	0	0	0	0	0	0	0	0	107
137-145	0	21	0	11	0	0	0	0	0	0	0	0	32
145-153	0	20	0	11	0	0	1	0	0	0	0	0	32
153-161	0	11	0	6	0	0	0	0	0	0	0	0	17
161-170	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	3751	241989	2110	28409	1275	830	275	1536	453	1537	156	1269	283590
Percentage	1.32%	85.33%	0.74%	10.02%	0.45%	0.29%	0.10%	0.54%	0.16%	0.54%	0.06%	0.45%	

Table 2. is a summary of the vehicular speed classification, 85.33% of vehicles that crossed the road tubes were cars, 10.76% were buses, 1.84% were trailers and tankers, 1.32 were cycles, 0.45% were 3-axle trucks and buses 0.29% were 4-axle trucks.

Table 3. Ogive Distribution

Mid-Point Speed	% Frequency
20	0.12
28	0.49
36	1.23
44	4.6
52	13.06
60	21.97
68	23.6
76	17.99
84.5	9.91
93	4.36
101	2.2
109	0.25
117	0.9
125	0.6
133	0.4
141	0.4
149	0.1
157	0.1
165.5	0

Cumulative Speed Distribution Ogive

The ogive derived from **Table 3.** displays the variance in the speed limits, showing the lowest speed was an average of 20Km/h with 0.12% of vehicles, the highest was 157Km/h with 0.1% of vehicles and 23.6% of the vehicles running at a speed of 68Km/h.

Table 4. Speed Distribution Table

Speed Class Interval l (Km/h) xl	Speed Mid point (Km-h) xl	No. of Vehicles (fl)	(fl) %	Flc	%	(xl)2	fl (xl)	fl (xl) 2
16-24	20	332	0.12%	332	0.12	400	6640	132800
24-32	28	1387	0.49%	1387	0.61	784	38836	1087408
32-40	36	3491	1%	5210	1.84	1296	125676	4524336
40-48	44	13038	4.60%	18249	6.44	1936	573716	25243504
48-56	52	37037	13.06%	55286	19.5	2704	1925924	100148048
56-64	60	62304	21.97%	117590	41.47	3600	3738240	224294400
64-72	68	66936	23.60%	184526	65.07	4624	4551668	309512064
72-80	76	51006	17.99%	235532	83.06	5776	3876456	294610656
80-89	84.5	28105	9.91%	263637	92.97	7140.25	2374873	200676726
89-97	93	12365	4.36%	276002	97.33	8649	114995	106944885
97-105	101	6244	2.20%	282246	99.53	10201	630644	63695044
105-113	109	723	0.25%	282969	99.78	11881	78807	8589963
113-121	117	262	0.09%	13689	99.87	13689	30654	3586518
121-129	125	171	0.06%	15625	99.93	15625	21375	2671875
129-137	133	107	0.04%	17689	99.97	17689	14231	1892723
137-145	141	32	0.01%	1024	99.98	19881	4512	636192
145-153	149	32	0.01%	1024	99.99	22201	4768	710432
153-161	157	17	0.01%	289	100	24649	2669	419033
161-170	165.5	0	0.00%	0	100	27390.25	0	0
		283590	1				19149614	1349376607

Table 4. is a summary of the vehicular speed classification: 85.33% of vehicles that crossed the road tube were cars, 10.76% were buses, 1.84% were trailers and tankers, 1.32 were cycles, 0.45% were 3-axle trucks and buses, 0.29% were 4-axles trucks.

From the data above, 66,936 vehicles 23.60% had an average speed of 67,6km/hr. The highest being 57,865 cars, followed by 6,855 buses, 1056 trailers/tankers, 783 cycles, 243-axle trucks, and 134 4-axle trucks/buses.

Table 5. Cumulative Distribution Curve Table

Mid-Point Speed	% Frequency
20	0.12
28	0.61
36	1.84
44	6.44
52	19.5
60	41.47
68	65.1
76	83.06
84.5	92.97
93	97.33
101	99.53
109	99.78
117	99.87
125	99.93
133	99.97
141	99.8
149	99.9
157	100
166	100

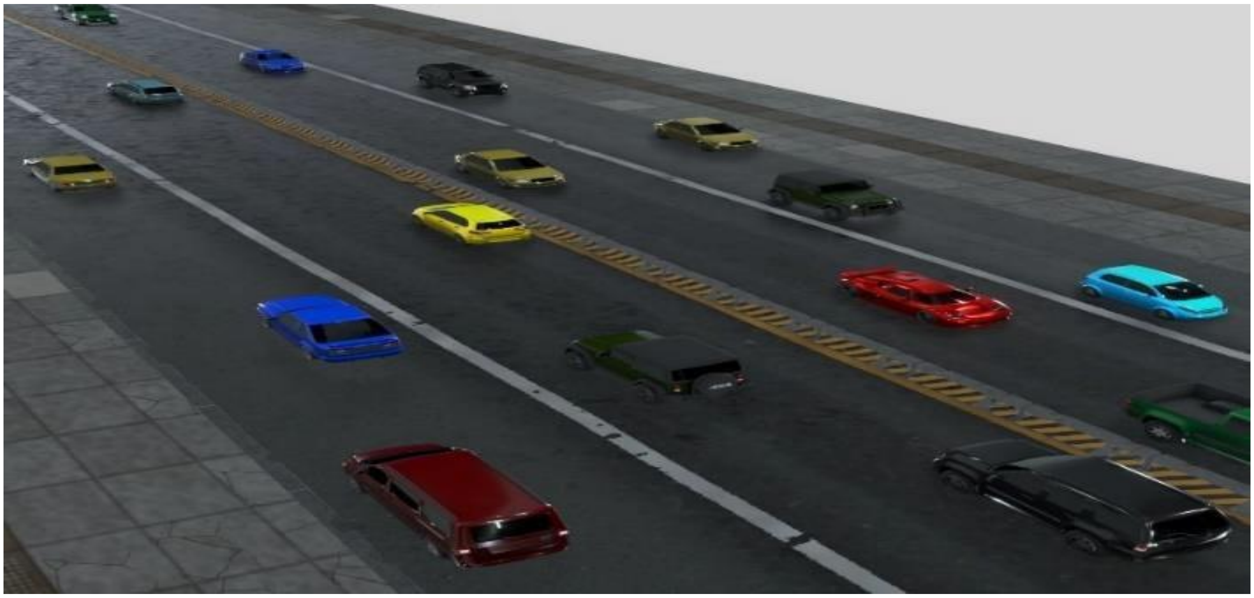

Figure 2. 3D drawing of a proposed four-lane, two-way road for adoption on the western by-pass road, FCT, Abuja, Nigeria.

Figure 5 depicts the standard representation of the proposed four-lane, two-way road designed for Adoption on the western bypass road, FCT.

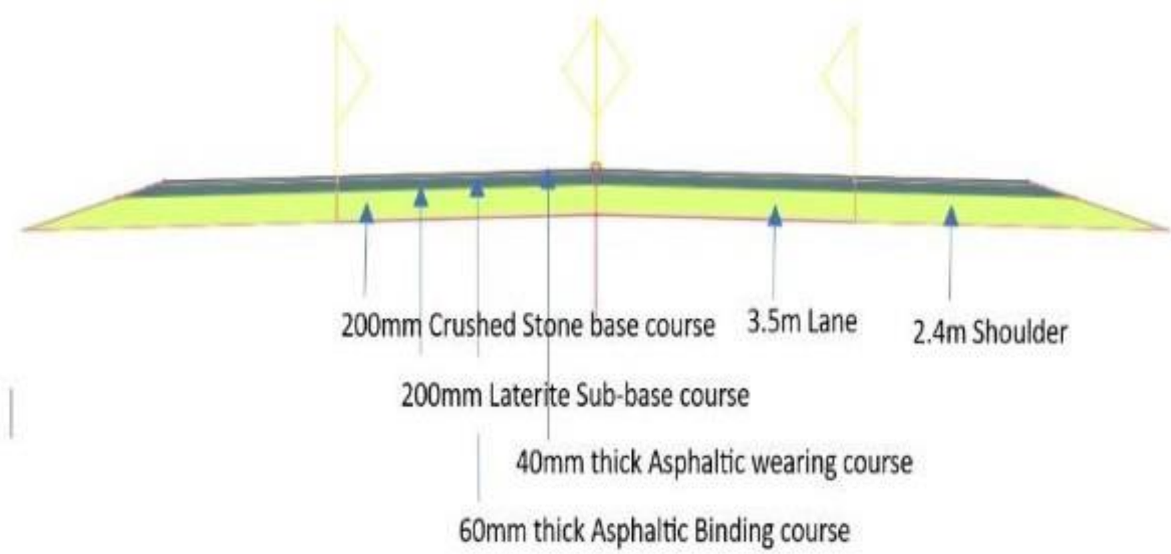

Figure 3. Existing Two-Lane, Two-Way Road Structure of The Western Bypass Road, Abuja, Nigeria.

This illustrates the parameters of the existing two-lane two-way road structure:

Stone base course 200mm

Sub-base course= 200mm

Thickness of asphaltic wearing course 40mm

The thickness of the asphaltic binding course is 60mm.

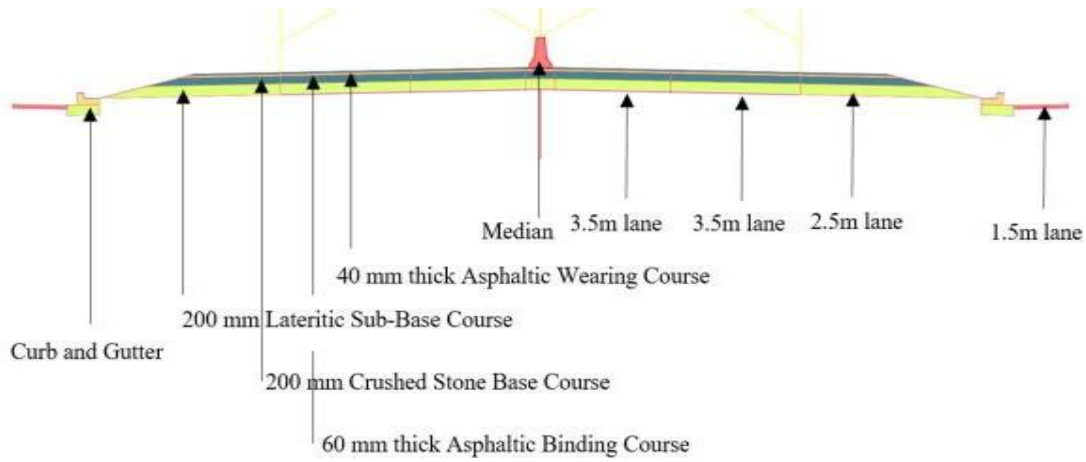

Figure 4. Proposed four-lane, two-way road structure of the western bypass road, Abuja, Nigeria.

This includes a geometric representation of a proposed four-lane, two-way road with measurements of:

Asphalt binding course =600mm

Stone base course= 200mm

Sub base=200m

The asphalt wearing course is 40mm, and the lane span is given as 3.5m for the lane and 2.5m for the shoulders, curb, and gutter. On the profile, annotations are drafted to denote the road positioned on the Surface area.

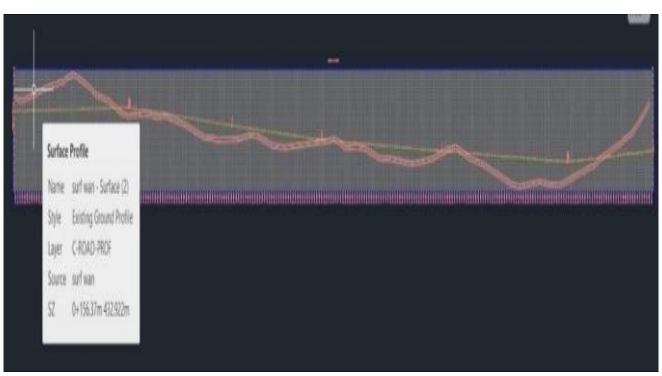

Figure 5. Surface Profile Grading of The Proposed Network.

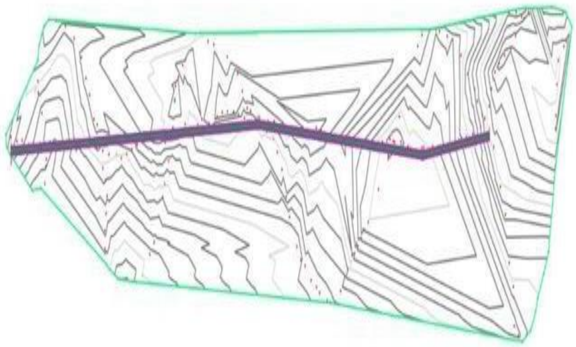

Figure 6. Topographical Outline of Existing & Proposed Network

This denotes the elevations and terrains on the network

4 | CONCLUSION

This study was carried out in seven (7) months. The basic aim of the study was achieved through the employment of the metro count device & and road tubes to compute collective PCH data. constraints. The research study on the geometric improvement of the existing Western Bypass Road is based on the Federal Republic of Nigeria Geometric Highway Design Manual (2013) considering geometric elements of the shoulder widths, lane width, and horizontal and vertical alignment. The existing road length of the road is 5.8km. The design speed of the current road is 68km/hr. The cumulative cut volume, cumulative filled volume, and cumulative net volume obtained were also obtained.

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Availability of Data and Materials:

Data available within the article or its supplementary materials.

Conflicts of Interest:

The authors declare that they have no conflicts of interest to report regarding the present study.

REFERENCES

1. Aryal, P. (2020). Optimization of geometric road design for autonomous vehicles.

2. Casal, G., Santamarina, D., & Vázquez-Méndez, M.E (2017). Optimization of horizontal alignment geometry in road design and reconstruction. Transportation Research Part C: Emerging Technologies, 74, 261–274.

3. Commonwealth, T. (1997). The Commonwealth of Massachusetts Highway Design Manual.

4. Daganzo, C. F. (1997). Fundamentals of Transportation and Traffic Operations. Fundamentals of Transportation and Traffic Operations.

5. De Leur, P., & Sayed, T. (2003). A framework to proactively consider road safety within the road planning process. Canadian Journal of Civil Engineering, 30(4), 711–719.

6. Dhall, S., Rab, S., Pal, S. K., Javaid, M., Khan, A. A., & Haleem, A. (2023). Identifying the feasibility of 'travellator roads' for modern-era sustainable transportation and its prototyping using additive manufacturing. Sustainable Operations and Computers, 4, 119–129.

7. Erua, J. B. (2017). Call Admission Control Scheme and The Desire for Prioritization In Mobile Networks. 4(6), 7505–7515.

8. Factors Affecting Geometric Design of a Highway – Transportation Engineering -Civil Engineering (CE) PDF Download. (n.d.). Retrieved January 14, 2024.

9. Fay, D. L. (1967). No Title No Title No Title. Angewandte Chemie International Edition, 6(11), 951–952.

10. Geerlings, H., & Stead, D. (2003). Integrating land use planning, transport, and

11. Aryal, P. (2020). Optimization of geometric road design for autonomous vehicles.

12. Casal, G., Santamarina, D., & Vázquez-Méndez, M.E. (2017). Optimization of horizontal alignment geometry in road design and reconstruction. Transportation Research Part C: Emerging Technologies, 74, 261–274. Commonwealth, T. (1997). The Commonwealth of Massachusetts Highway Design Manual.

13. Daganzo, C. F. (1997). Fundamentals of Transportation and Traffic Operations. Fundamentals of Transportation and Traffic Operations.

14. De Leur, P., & Sayed, T. (2003). A framework to proactively consider road safety within the road planning process. Canadian Journal of Civil Engineering, 30(4), 711–719.

15. Dhall, S., Rab, S., Pal, S. K., Javaid, M., Khan, A. A., & Haleem, A. (2023). Identifying the feasibility of 'travellator roads' for modern-era sustainable transportation and its prototyping using additive manufacturing. Sustainable Operations and Computers, 4, 119–129.

16. Gibreel, G. M., Easa, S. M., Hassan, Y., & El-Dimeery, A. (1999). State of the art of highway geometric design consistency. Journal of Transportation Engineering, 125(4), 305–