3D Model for Highway Alignment

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Abstract: ***Highway planning is often complex and time consuming because of the multifaceted nature of highway design. Transportation design and analysis has been conducted mostly in 2D and reported as time consuming, and error-prone manual drafting updates. When planning for a new highway alignment, the general practice is to identify multiple alignment options and determine the best option based on multiple factors. This research intends to build a 3D object based intelligent design model of the roadway in which elements of the design are related to each other dynamically. In order to test the feasibility of the proposed approach, a prototype object based 3D model was developed and tested on a highway project in*** **Vadakkencherry.**

Keywords: Highway planning, 3D Model, Highway Alignment, Multifaceted, Prototype

1. Introduction

Highways provide maximum flexibility for travel with reference to route, direction, time and speed of travels. The economic growth of a community is dependent upon highway development to enhance mobility. When a new alignment is proposed it should be short, easy safe and economical. The factors' controlling the alignment is obligatory points, traffic, geometric design, economics, and other considerations.

The paper deals with the proposal of a new alignment to reduce the traffic congestion. This project propose an alignment from NH 47 (Thankam junction) to Mangalam dam road passing through Karunya medical college using 3D visualization.. Without the use of three-dimensional (3D) modelling, highway planning experiences a significant difficulty. Cut and fill calculation process tends to consume a significant amount of time. Inaccurate earthwork calculations lead to increased overall costs for the highway project. Identifying accurate cut and fill volumes early in the highway planning phase can help reduce total costs of the project. By using the object-oriented approach, the process of cut and fill calculations can be performed automatically and in an accurate manner.

The studies have explained in detail about the complex process of highway alignment optimization (HAO).So a model was developed to solve for the three-dimensional alignment of a highway segment. It also explained about the research procedure to improve current highway design and construction practices by applying a 3D object oriented modelling approach to solve the problem of time-consuming highway planning. Hyunjoo Kim (2015) have provided a technical review between BIM and GIS and measure the different strengths and weaknesses of each approach. Sabyasachee Mishra (2014) have considered environmental emission and proposed two separate approaches in the highway alignment optimization (HAO) process. Zhenhua SHEN et al. (2014) have developed the 3D model based on the STEP (Standard for the Exchange of Product model data), which is an open standard, and is used as data structures. Koji Makanae (2014) have developed a virtual model in the design process. The concept of information propagation was summarized in the construction process and analysed the information flow in the process of highway design. P.P.A. Zanen et al. (2013) provided a modelling method that views highway projects as an integral part of the area in which they are constructed. Ragab Khalil (2013) through GIS programs they provided various built-in and add-in tools to perform transformations. Joseph M. Wheaton (2012) have developed a CHaMP Transformation Tool based on simple ArcGIS. Min-Wook Kang (2011) has presented an intelligent optimization tool that assists planners and designers for finding the optimum highway alignments, connecting specified endpoints or zones. It integrates genetic algorithms with a geographic information system (GIS) for optimizing highway alignments and processes massive amounts of relevant data associated with highway design and alternative evaluation.

2. Methodology

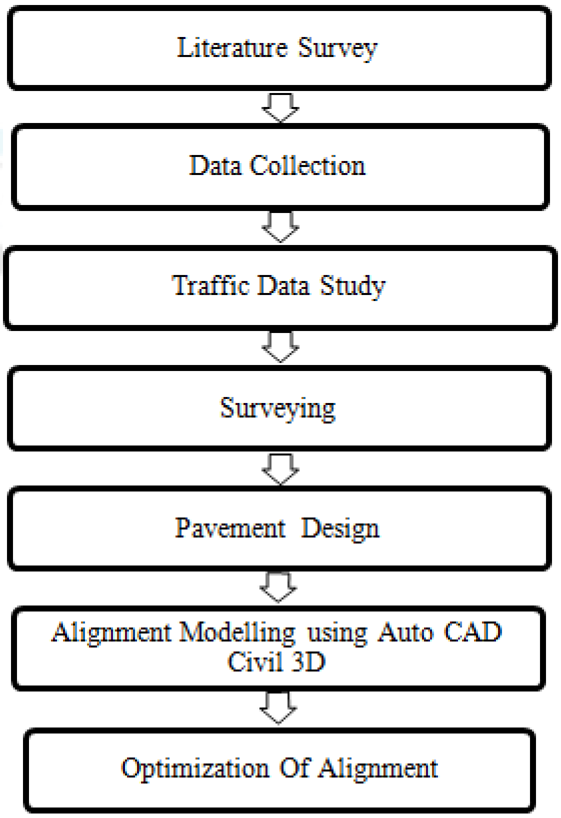

Figure 1: Methodology of the project

3. Study Area

The site selected for the project is located near Vadakkencherry in Palakkad district. The area lies on the geographical coordinates of 10°46'21''N, 76°39'5''E. The total area of the site is 185192.78 m^2. Majority of the plot is agriculture land consisting of plain terrain. The area is about 1585.08 meters above sea level. The important milestone in the area is Government higher secondary school, CVM high school, Kattukulangara Temple, Karumanaserry Temple, Ganapathi Temple and Jama Masjid Mosque. Figure 2 shows the satellite image of the proposed site.

Figure 2: Selected site for the project

4. Traffic Data Study

For estimating design traffic the cumulative number of standard axles carried by the pavement during the design life is considered. This requires the following information:

1. Initial traffic in terms of CVPD
2. Traffic growth rate during the design life
3. Design life in number of years
4. Vehicle damage factor (VDF)
5. Distribution of commercial traffic over the carriage way.

Initial traffic is determined in terms of commercial vehicles per day (CVPD). Estimate of the initial daily traffic flow, was done on the basis of potential land use and traffic on existing routes in the area. Traffic growth rates were estimated by studying the past trends of traffic growth. From adequate data the average annual growth rate of 7.5 percent was adopted. The design life of SH, NH is taken as 15 years. The vehicle damage factor for plain terrain as is 4.5. The vehicle distribution factor is 50% of the commercial vehicles in both directions. The traffic volume was studied at two locations. Table 1 shows the traffic volume date on Manikyapadam road from 6:00 am to 10:00 pm at the intersection to NH 47 for three days and shows total number of commercial vehicles in a day. Table 2 shows the traffic volume date on Mangalam dam road from 6:00 am to 10:00 pm at the intersection to SH 58 for three days and shows total number of commercial vehicles in a day. The peak time of vehicles in 2 days is between 4:00 pm to 5:30 pm.

Table 1: Traffic volume of Manikyapadam road

Day	Bus(nos)	Mini Bus(nos)	Cars/Jeep/Van(nos)	Trucks(nos)	Motorized 2 Wheeler(nos)	LCV(nos)	Total(nos)
11/09/2015	355	122	994	94	1708	407	3680
12/09/2015	247	124	1108	105	1706	412	3702
13/09/2015	116	107	1101	106	1709	414	3553
Average	239	114	1068	102	1708	409	3645

Table 2: Traffic volume of Mangalam dam road

Day	Bus(nos)	Mini Bus(nos)	Cars/Jeep/Van(nos)	Trucks(nos)	Motorized 2 Wheeler(nos)	LCV(nos)	Total(nos)
5/09/2015	356	128	1007	140	1716	406	3753
6/09/2015	244	126	1101	106	1709	414	3700
7/09/2015	408	144	1095	148	1738	413	3946
Average	336	132	1067	131	1721	411	3800

5. Surveying

Before a highway alignment is finalised in highway project, the engineering survey are to be carried out. The various stages of engineering surveys are;

- Map study (Provisional alignment Identification)
- Reconnaissance survey
- Preliminary survey
- Final location and detailed surveys

Map study gives a rough guidance of the routes to be further surveyed in the field. Reconnaissance survey was done to confirm features indicated on map. From the reconnaissance survey general character of the area in field for deciding the most feasible routes for detailed studies was examined. The preliminary survey was done to study the various alternative alignments proposed after the reconnaissance and to collect all the necessary physical information and detail of topography, drainage and soil. Detailed surveying was done using Trimble total station. A total station is a combination of electronic theodolite, electronic distance measuring device (EDM) and a micro-processor with a memory unit. This combination makes possible to determine the coordinates of reflector aligning the instrument cross hairs on the reflector and simultaneously measuring the vertical and horizontal angles and slop distance. Figure 3 shows data collection compounds using Trimble total station.

Figure 3: Date collection compounds using total station

Using Trimble total station the coordinates from the proposed site was collected. The total station was first set up on a point. Surveying the area of site would require relative coordinates, therefore, the initial instrument X, Y, Z coordinates was set to 1000, 1000, 100. Then the total station was oriented with "back- sight azimuth" setup which uses bearing to the backsight point, using assumed bearing for the line connected the two points. Once the survey is begun on this assumed coordinate system, all additional station setups and all data, including three control points (which acquired during the survey course), collected in a single unprojected local assumed coordinate system. The northing easting and elevation of the ground co-ordinates was found out. Table 3 shows the sample of the co- ordinates of the ground.

Table 3: Co-Ordinates

POINTS	X	Y	Z
1	1000	1000	100
n	1002.035	1000	99.938
A9	99181.81	99789.98	98.409
205	99259.3	99848.16	97.257
206	99245.82	99825.64	96.626
207	99345.43	99877.37	96.444
208	99225.18	99803.57	97.669
209	99225.89	99810.11	97.773
210	99240.58	99822.98	96.573
211	99216.41	99809.38	96.784
212	99212.99	99812.34	96.668
215	99214.47	99814.92	96.769

6. Soil Investigation

Samples are collected from the location. The soils were taken upto a depth of 50cm from the ground level. The different works carried out on the samples are consistency test, heavy compaction and California bearing ratio test. The test results are used to design the pavement. Consistency limits test help to get information about the soil to estimate strength and settlement characteristics. From CBR test result the pavement thickness and from compaction test the optimum water content of soil can be determined. Samples were collected from Manikyapadam road (sample 1) and Mangalam dam road (sample 2). The test results are shown in Table 4.

Table 4: Test Result

Sample	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Max Dry Density (g/cc)	Optimum Moisture Content (%)	CBR Value (%)
1	46	14.56	31.44	2.15	15.1	10.6
2	43	13.41	29.59	2.29	11.34	11.6

From the Casagrandes plasticity chart in the soil is classified as low plasticity clay and from the CBR value the sub grade strength is good and capping is not required.

7. Design of Pavement

Total number of commercial vehicles, P = 3800

Soaked CBR for sample = 10%

The design traffic, N = $\{(365 \times [1+r]^n - 1)/r\} \times A \times D \times F$

N = the cumulative number of standard axles to be catered for in the design in terms of msa
A= Initial traffic in the year of completion of construction in terms of the number of commercial vehicles per day
D = Lane distribution factor = 0.50
F = Vehicle damage factor = 4.5
n = Design life in years = 15 years
r = Annual growth rate of commercial vehicles (r = 0.075)
x = No: of years between the last count and year of completion = 2016-2014 =2
A = $P\,(1+r)^x$
N= 141 msa

The cumulative number of standard axles to be catered for in the design in terms of msa,

N = 141 msa

From the pavement thickness design chart for traffic 10-150 msa andfrom the Pavement thickness catalogue Plate 1-recommended design for cumulative traffic (msa) range 10 - 150msa for CBR value 10% the flexible pavement have a total thickness of 650mm. The thickness of each layer is shown in Table 5.

Table 5: Pavement Thickness

Pavement Composition	*Thickness(mm)*
Asphalt Concrete	50
Dense Bituminous Macadam	150
Granular Base Course	250
Granular Sub Base Course	200

8. Alignment Proposing

The alignment proposing is done using Auto CAD Civil 3D software. AutoCAD Civil 3D is engineering software which provides civil engineering professionals with targeted solutions for a wide variety of infrastructure projects, including land development, transportation, and water projects. This application creates intelligent relationship

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between objects so the design changes can be dynamically updated. Using AutoCAD Civil 3D, we can compare the design of road elements against recognized industry standards or user defined standards. As designers work to lay out designs, the software provides graphic alerts and/or notification tips to help alert you when standards are not met. This is made possible using design criteria and design check sets. Design speed can be assigned to each alignment.

Three alignments are proposed using the software in the area. The surface is generated in the software from the survey co-ordinates. Alignment 1, alignment 2 and alignment 3 have a design speed of 100km/h, 80km/h and 80km/h respectively. The 3 alignments have a total thickness of 650mm.Figure 4Shows the Highway Construction Project as Represented in Civil 3d.Thealignment 1, alignment 2, and alignment 3 have a total length of 5km, 5.7km and 7km respectively.

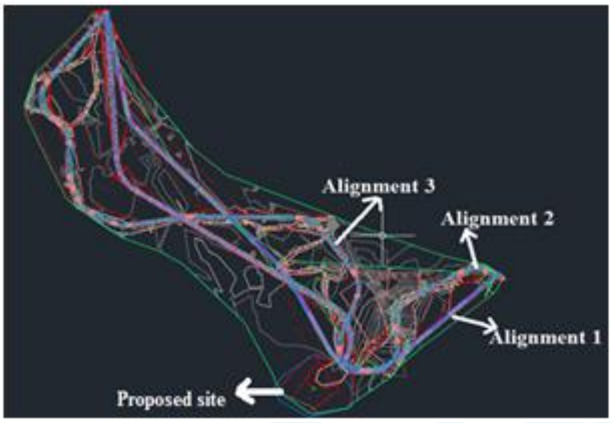

Figure 4: Alignment Represented In Civil 3d

8.1 Cut and Fill Calculation

One of the major factors in highway construction is cut and fill calculation. Cut and fill operations account for approximately 25% of the total construction cost in road construction projects. Prior to the use of CAD software in the construction industry, manual or basic computer models were used for earthwork planning. Identifying accurate earthwork quantities during the construction planning phase is such an important area that many researchers have attempted to implement many technologies and methods to improve the process. The Auto CAD Civil 3D software gives a detailed report of the cut and fill calculation for the alignment. The net graph displaces the graphical percentage of volume surface or bounded area shown in figure 5. According to the cut and fill calculation alignments 1 have got more fill value.

Figure 5: Graphical Percentage of Volume Surface or Bounded Area

8.2 3D Representation

The 3D wireframe model is an edge or skeletal representation of a real-world object. Acording to the design speed, total length, and cut and fill culculation alignment 1 is considered as the optimum alignment. Figure 6 shows the render image of the alignment 1 near the proposed site of the medical collage and figure 7 shows infraworks image of the alignment 1.

Figure 6: Render Image

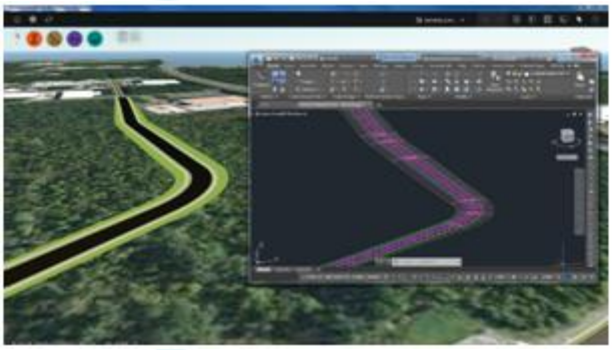

Figure 7: Shows Infraworks Image

9. Conclusion

When a new alignment is proposed in an area multiple alignments have to be considered and from this optimum alignment have to be selected. In this project object-oriented 3D model is developed using the software Auto CAD Civil 3D. Three alignments is proposed in the area. According to the total length, design speed and cut and fill calculation alignment 1 is selected as the optimum alignment. The new alignment reduces the traffic congestion and distance to reach the nation highway.

Reference

[1] Hyunjoo Kim and Zhenhua Chen, "Integration of BIM and GIS: Highway Cut and Fill Earthwork Balancing", American Society of Civil Engineer, pp. 468-474., 2015.

[2] Jie Wang and Gary Lawson, "Automatic high-fidelity 3D road network modeling based on 2D GIS data", ELSEVIER Journals, Advances in Engineering Software, pp. 86-96., 2014.

[3] Koji Makanae, "Optimization of Highway Geometric Design Process for Computer-based Design", American Society of Civil Engineer, pp.13766-1383., 2014.

[4] P.P.A. Zanen c and T. Hartmann, "Using 4D CAD to visualize the impacts of highway construction onthe public",

[5] ELSEVIER Journals, Automation in Construction, pp. 136-144., 2013

[6] Sabyasachee Mishra1, Min-Wook Kang, and Manoj K. Jha, "Empirical Model with Environmental Considerations in Highway Alignment Optimization", American Society of Civil Engineer, pp. 1-1., 2014.
[7] Ragab Khali, "Object Based Optimization of Highway Alignment", American Society of Civil Engineer, pp. 358-369., 2013.
[8] Zhenhua SHEN and Kevin ORR, "Object Based 3D Intelligent Model for Construction Planning/Simulation in a Highway Construction", American Society of Civil Engineer, pp. 258-269., 2014