Comparative Analysis of Geometric Design Using Different Tools: A Review

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Abstract- *Given India's fast population growth, there is a corresponding rise in traffic. Further transport facilities are being developed as a result of India's infrastructural development. The measurement and arrangement of the road's visible elements, including alignment, written distance, cross-section, and intersection, are controlled by the geometric design..*

The goal is to maximise alignment while meeting design standards and constraints. Manually designing geometric shapes takes a lot of effort and is prone to expensive mistakes. In the process of designing roads, the road alignment is created, the alignment profile is charted using bearings or coordinates (easting and northing), stations, and elevations of points along the proposed route, sight distances, radii of horizontal curves, lengths of vertical curves, earthwork quantities, and many other studies and calculations are performed.

Keywords- AutoCAD Civil 3D, MX ROAD, Horizontal alignment, Vertical profile, Surface analysis, Alignment design.

I. INTRODUCTION

A new route's alignment is greatly influenced by geometric design, which is a crucial component of the current style. Geometric design is a basic element of every road alignment. Among other significant factors, it addresses cross-sectional elements, sight distance considerations, horizontal alignment and vertical alignment details, intersection elements, design speed, topography or terrain, traffic factors, design hourly volume and capacity, and environmental factors. For a new road to be safe and comfortable for traffic, it must be short, easy to use, safe, and economical. The roadways' geometric structure is composed of three fundamental elements: cross-sectional orientation, vertical orientation, and horizontal orientation. For efficient traffic flow, highways must be designed to provide user comfort and safety.

OBJECTIVES OF THE RESEARCH

- Comparative study of geometric design of road using AutoCAD Civil 3D and MX ROAD Software.
- To upgrade or to improve the geometric features using both AutoCAD Civil 3D and MX ROAD.
- Reduce the cost of road development and it's designing.
- To improve the road life by efficient design.
- Designing effective vertical and horizontal alignment.
- To evaluate the advantages and limitations of each software
- To provide recommendations on the most suitable tool for Indian highway projects.

II. LITERATURE REVIEW

The literature evaluation offers a starting point for comprehending the theoretical frameworks, instruments, and techniques pertinent to highway geometric design as well as the function of contemporary software platforms like AutoCAD Civil 3D and MX Road. This chapter reviews earlier studies on CAD applications, comparative analysis, and highway design. Establishing the evolution of geometric design principles, evaluating the importance of design standards in India and around the world, analysing the use of AutoCAD Civil 3D and MX Road in highway projects, and identifying knowledge gaps that drive the current research are the goals of the review.

Review of Literature Survey

Renaldi Agustian et.al (2025) planned to use the AutoCAD® Civil 3D application to analyse the geometric planning of village roadways. The data and planning location is located in Majalengka Regency, Indonesia, on Village Road. Using the AutoCAD program to digitise manual planning is the research methodology employed. AASHTO and Indonesian standards are combined in the planning standard.

The study's findings demonstrate that the best planning precision, speed, and convenience are achieved when village roads are planned using AutoCAD® Civil 3D.

Ankit Verma and Akhilesh Nautiyal (2023) The OpenRoads program was used to create the project's design values, which took into consideration the project corridor's current features as well as all of the Indian Road Congress's (IRC) requirements. A carriageway of 30 meters, a control line width of 100 meters, and a 50-meter gap between the building lines make up the cross-section elements, and the design speed has been set at 50 kmph. The carriageway width is 7.5 m, the shoulder width is 2.4 m, and the overall width of the road is 13.0 m. The majority of the alignment passes over steep, hilly terrain, with a high curvature that usually surpasses 200 degrees per km and a cross slope of 45% to 60%. Even a few places throughout the road have high inclines. Due to the road's alignment along the hill's face, the project road has a hill on one side and a valley on the other. It has been established that the maximum super elevation is 7%, while the cross-slope or camber is 2.5% for bituminous surfaces and 3.5% for earthen surfaces. Furthermore, a 0.6-meter additional carriageway widening will be implemented at curves. Since there is a lot of traffic on this stretch connecting different tourist destinations, the project's primary objective is to address transport issues like congestion and traffic. High traffic volumes and traffic congestion have been resolved by the new highway design, which also ensures smoother vehicle movement.

Prashant Agarwal et.al (2023) Autodesk Civil 3D revolutionises roadway design while saving time and minimising errors. In addition to maintaining engineering standards, it offers comprehensive solutions. Real-time analysis speeds up the process, and tasks are automated. Numerous data types and complex situations can be examined in future studies. By collecting traffic data and accurately aligning the roads, the algorithm streamlines the process. Specifications are met by spiral transition curves, and all curves follow the guidelines. Geometric design is straightforward to apply, enables checks, and enhances geometry while creating 3D roads with Autodesk Civil 3D. It facilitates accurate computations, the application of super elevation, assembly, and the creation of corridors. In conclusion, Autodesk Civil 3D gives designers efficient tools for building roadways.

Amit S. Chame et.al (2022) Analysing the highway's existing geometry, identifying accident-prone regions, and identifying safety issues with the highway's design were the goals. It should be reasonably priced and have a simple geometric design that meets the demands of all road users, including vehicles, cyclists, and pedestrians.

According to the findings, it is essential to design according to standards and rules since geometric design principles increase road users' comfort and safety. Because they are more likely to be involved in accidents, curved sections should be given more consideration while designing highways. According to IRC regulations, the carriageway, camber, shoulder, and design speed are all decided in order within a certain stretch.

Litwina Ratri Rosaria et.al (2022) The Corn Drying Centre Post-Harvest Infrastructure industrial sector in Tuban, East Java, served as the focal point of the geometric road plan for the horizontal paragraphs. Bend radii are considered in the design to compensate for daily vehicle flows, the heaviest axis stresses, and a limited land space. The outcomes of conducted surveys yield quantitative information that is consistent with data collected in the field. The results of the computations are displayed using AutoCAD Civil 2D.

The Spiral-Circle-Spiral (SCS) arch, which is the result of the horizontal arch that can be used, measures 111.83 meters in total horizontal curve length. AutoCAD Civil 2D® can be used to illustrate horizontal arches. In addition to the horizontal arch calculation, it was found that a supporting width of 0.63 meters was added to allow large vehicles and that the bend pavement required to be widened by 1.03 meters.

Prasanna P N et.al (2022) In order to give a comparative analysis of road geometric design, the research used two analytical applications: AutoCAD Civil 3D and MX Road. This procedure ought to lower the price of road construction and design while also enhancing road life through effective design. Effective vertical and horizontal alignment, super elevation, and further widening when needed are all designed. According to the findings, AutoCAD Civil 3D is regarded as being very beneficial and easy to use. The highway geometrics and AASHTO were also taken into account as safety precautions, according to IRC. In addition to producing a vertical profile and horizontal alignment, it also made cross-segmentation possible. Road widening at super elevation and horizontal geometry needs to be properly considered. Each curve in the project is plotted in accordance with the IRC Standard.

Ashish Kale et.al (2021) Geometric design is a key element of the current style and has a significant impact on aligning a new route. The fundamental component of every road alignment is geometric design. In addition to design speed, topography or terrain, traffic factors, design hourly volume

and capacity, environmental factors, and other important factors, it deals with cross-sectional elements, sight distance considerations, horizontal alignment and vertical alignment details, and intersection elements. When aligning a new road, it should be quick, simple, safe, and cost-effective. It should also be safe and comfortable for movement. The three basic components of the roads' geometric structure are cross-sectional orientation, vertical orientation, and horizontal orientation. They together provide a road layout in three dimensions. Curves, tangents, and transitions are the three geometric elements that make up horizontal alignment. A longitudinal section combined with geometric additives like gradients, sag curves, and crest curves is known as vertical alignment. Depending on selection and estimation, highway geometry formulas follow specific design criteria, such as sight distance, vehicle stability, driver comfort, drainage, economy, and aesthetics. There are a lot of calculations and measurements that follow the design process. This paradigm has been altered by the Civil 3D upgrade to allow for the simultaneous execution of design and development. Geometrical design can be extremely laborious, time-consuming, and prone to expensive errors when done by hand. Additionally, the conventional method is predicated on a two-dimensional study that does not guarantee a visually appealing arrangement. The purpose of this study is to demonstrate how geometrical design can be completed efficiently and accurately in a short amount of time so that specialists in developing nations might utilise it for road design. In order to save time and effort, this paper presents a typical highway design using AutoCAD Civil 3D. In the absence of 3D models, designing highways presents many difficulties. That quantity requires a lot of work to cut and fill. It is possible to employ the volume computing method.

Bhashkar and Dr. A.K. Mishra (2021) Using MXROAD and IITPAVE software, the MDR26B will be designed for a 13.62-kilometre section of Uttar Pradesh between Chitrakoot Dham and Pahari Bujurg. The road will be upgraded from a single carriageway with two lanes to a dual carriageway with two lanes on each side. In accordance with IRC: 37-2018, the flexible pavement was created using IITPAVE Software and a mechanistic-empirical methodology, which is more reliable and scientific than the conventional empirical technique. An interlayer AIL (granular crack relief layer) is placed on top of the cement-treated base and at the intersection of the bituminous layer and the cement-treated base to help reduce cracks. In addition, a foamed bitumen/bitumen emulsion-treated RAP (with or without virgin aggregates) layer between the bituminous layer and Cement Treated Base and Cement Treated Sub-Base has been designed, investigated, and contrasted with the conventional Granular Base and Granular Sub-Base. Consequently, this technique will save time and money while increasing accuracy and safety through the use of IITPAVE Software. It is also possible to rapidly and easily produce a comprehensive report for each part by using MXROAD and flexible pavement design software.

Dipali Purushottam Paunikar (2021) illustrates the typical road design using AutoCAD Open Road as support. Modelling is made easier and more comfortable with the use of modelling software.

The results indicated that the geometric design of highways using Open Road is very helpful and easy to utilise for three-dimensional road design. Open Road gives designers and analysts access to a worldwide platform by supporting design tests for various codes. Both horizontal and vertical geometry improved in the shortest amount of time to meet the required criteria. For highway planning, Open Road is a handy tool for creating an assembly and corridor.

Shubham Dhamne et.al (2021) In the Civil-3D environment, the research's goal was to design a clearly defined highway corridor for a given case study. Superelevation was calculated using the IRC design criteria, which also included widening on curves, providing appropriate carriageways, shoulders, and kerbs when needed, and using the profile building tools to create vertical curves and grade lines.

Road modelling with real-time analysis and designer feedback, combined with a criteria-based design, speeds up the design process and reduces troublesome situations, according to the results. In addition to complying with all safety regulations, the road's geometry was designed in compliance with the IRC. The creation of the working cross-section, vertical profile, and horizontal alignment is underway. The design process may be completed quickly and comfortably with AutoCAD Civil 3D, which also saves a great deal of time and work. The capabilities of AutoCAD Civil 3D minimise the major drawbacks of a manual design approach, which is laborious, time-consuming, and prone to costly errors.

Akash Surendra Kolamkar et.al (2020) India is a nation whose population is expanding quickly, which means that traffic is also rising there. The development of rural areas also expands the resources available for the advancement of transportation infrastructure. The road's alignment, sight distance, cross-section, and crossings are among the visible aspects whose proportions and arrangement are controlled by the geometric design. The primary goal is to minimise expenses and environmental harm while maximising highway traffic efficiency and safety. The next step to increase their usefulness is to learn software that will allow them to employ

the foundations of road geometry, which are already known to the designers. Plotting the alignment profile and creating the road alignment using bearings or coordinates (easting and northing), stations and elevations of points along the proposed route, lengths of vertical curves, calculating the quantity of earthwork, and many other analyses and calculations are all part of the geometric design of a road. The goal is to find the best alignment while meeting design standards and considerations. Manually designing geometric shapes takes a lot of effort and is prone to expensive mistakes. Numerous software programs, such as Bentley MX Road and AutoCAD Civil 3D, are currently on the market and are used to design the geometry of roads. The use of computer systems to design the geometry of roadways has adapted to current trends. Using AutoCAD Civil 3D software, this dissertation provides a comprehensive geometric design of a road project. The project's primary goal is to demonstrate how precise geometric design may be completed in a short amount of time. The process of designing a road with AutoCAD Civil 3D has been demonstrated. This software helps users save time and effort while providing clarity. Software for engineers called Civil 3D is used to plan, develop, and oversee civil engineering projects. The majority of users of this software are professionals and civil engineers.

Payal Gaikawad et.al (2020) AutoCAD Civil 3D was used to illustrate the typical roadway design. Survey information and topographical data from LIDAR or similar technologies are used by AutoCAD Civil 3D. Geometry can be examined and assessed using the IRC model and the Civil 3D built-in program's parameters after alignment has been established. After horizontal geometry is established, vertical geometry can be improved. In order to analyse both horizontal and vertical geometry without requiring laborious computations, Civil 3D offers integrated tests for transition length and sight distance.

The results showed that using AutoCAD Civil 3D to help with highway geometric design is very helpful and easy to use for three-dimensional road design. AutoCAD Civil 3D offers a global platform for design and analysis by supporting design checks for many codes. Both horizontal and vertical geometry improved in the shortest amount of time to meet the required criteria. When it comes to highway design, AutoCAD Civil 3D is a handy tool for creating assemblies and corridors. It is possible to calculate the amount of earthwork precisely and to calculate and apply super elevation in accordance with standards.

Sagar B. Patil et.al (2019) Using a post-and pre-analysis technique, the goal of the study of road geometry and accident rate is to identify different road geometric features. It has an impact on accident rates and geometric aspects. Traffic volume is the foundation of the investigation. Speed, loss of vision, horizontal radius, super elevation, high gradient, and vertical gradient all contributed to serious incidents. A total of 18749 vehicles (mixed vehicles) were gathered on Waghbil Road between the hours of 8:00 am and 8:00 pm for the analysis approach. The analysis displays the vehicle count ratio for each 15-minute interval. The investigation's goal was manual calculation. The project's primary focus is road and human safety, and the fundamental approach is used to gain a deeper understanding. This project's fundamental methodology involves researching, evaluating, and making decisions. The physical characteristics of the road, such as super elevation, horizontal radius, horizontal alignment, visibility, and gradient analysis, were examined at the Waghbil site in this study. The provision of a bypass, speed limit signs, divergence signs, and road studs was therefore determined to be necessary for safe driving in order to lower the accident rate. Measures to prevent Waghbilroad: There is a lot of traffic on this road. Signs with speed limits and diverging lanes should be installed to help minimise traffic. At the curves, road studs should be installed to prevent collisions and guarantee safe driving.

Yogesh Bajpai et.al (2019) India is a nation whose population is expanding quickly, which means that traffic is also rising there. The development of rural areas also expands the resources available for the advancement of transportation infrastructure. The road's alignment, sight distance, cross-section, and crossings are among the visible aspects whose proportions and arrangement are controlled by the geometric design. Geometric design takes a lot of time and is prone to expensive mistakes when done by hand. Road geometry is currently designed using a variety of software programs, including Bentley MX Road, HEADS, AutoCAD Civil 3D, and others. Current practices have been modified to use computer programs for designing the geometry of roads. This software helps users save time and effort while providing clarity. The goal of this research is to use Civil 3D software to provide a thorough analysis of the geometric design of a road project. Civil 3D is an engineering software program used for planning, developing, and overseeing civil engineering projects. Experts and civil engineers typically utilise this program. The goal of this project is to use Civil 3D to quickly and accurately design the road alignment. For the construction of roads, the survey data is required. Utilising a whole station can expedite and expedite the completion of the study. The points in Civil 3D are x, y, and z coordinates that are easting, northing, and elevation, and they are imported via a total station. These ground data coordinates are particularly helpful for designing alignments, creating surfaces, and creating other geometric characteristics.

Mohd. Khaja Nazimuddin et.al (2017) The goal of the research was to tie the road geometric design to the design standards used in the software and import it into the program. Every upgrade is intended to be made inside the suggested right-of-way. At significant cross-drainage portions, the proposed alignment is intended to coincide with the current alignment. Design speeds of at least 30 kmph and up to 100 kmph are the governing design speeds. There are two small intersections along the proposed path where the speeds are limited to a minimum due to a minimum horizontal curve radius. A small number of sections where site limitation is prevalent use limiting gradient values. The basic traffic volume data that was obtained has been predicted for 15 years (2017–2032). Using MXROAD allowed for high design precision and time savings.

S.A. Raji et.al (2017) Creating the road alignment and plotting the alignment profile using bearings or coordinates (easting and northing), stations, and elevations of points along the proposed route are just a few of the tasks involved in roadway geometry design. Other calculations and analyses include calculating sight distances, the radii of horizontal curves, the lengths of vertical curves, calculating earthwork quantities, and much more. The goal is to find the best alignment while meeting design standards and constraints. When done by hand, geometric design is very laborious, time-consuming, and prone to expensive mistakes. Today's developments are focused on designing roadway geometry using computer programs. The programs save a great deal of time and work and provide incredible precision. This article uses AutoCAD Civil 3D software to give a complete geometric design of a typical highway. The project's goal was to show how easily and precisely roadway geometric design may be completed in a short amount of time. The AutoCAD Civil 3D road design process has been demonstrated. The identical road was likewise geometrically designed by hand; the outcomes differed favourably from AutoCAD Civil 3D's. The roadway geometric design process is completed quickly, easily, and with remarkable accuracy when AutoCAD Civil 3D is used. AutoCAD Civil 3D's capabilities minimise the main drawbacks of the manual design method, which is laborious, time-consuming, and prone to expensive mistakes.

Harshil S. Shah and P.A.Shinkar (2016) The goal of the study was to use Autodesk Civil 3D to design the geometric components of the proposed road and design a road that is safe for all users to travel on at adequate speeds.

A minimum design speed of 30 kmph and a ruling design speed of 80 kmph were the design speeds that were developed, according to the results. One minor intersection where the speeds are limited to the minimum is where the proposed alignment reaches the minimum horizontal curve radius. The base traffic volume data that was gathered has been predicted for 15 years (2016–2031). With Autodesk Civil 3D, high design precision and time savings were accomplished.

III. CONCLUSION

A significant body of research has been devoted to evaluating the effectiveness of computer-aided design tools in highway geometric alignment, with particular focus on AutoCAD Civil 3D and MX Road. Both software platforms have gained prominence in highway engineering due to their ability to automate complex calculations, streamline drafting processes, and ensure compliance with design standards. In a comparative study, Prasanna, Prakash, and Suhas (2022) assessed the geometric design of highways using Civil 3D and MX Road, highlighting that while both platforms produced results within acceptable tolerances for curve radius, superelevation, and transition lengths, Civil 3D provided greater flexibility in visualization and real-time modification, whereas MX Road was more efficient in generating standardized outputs suited to Indian Road Congress (IRC) specifications. Their findings underscore that differences in software are less about accuracy and more about usability, adaptability, and workflow integration.

Other studies, though not always comparative, reinforce these conclusions. Mandal, Pawade, and Sandel (2019) demonstrated how Civil 3D enhances geometric design efficiency by integrating horizontal and vertical alignment with corridor modeling, which reduces human error and supports faster design iteration. Their work emphasizes that Civil 3D allows for improved visualization through 3D modeling, which aids in decision-making during the planning and construction phases. Complementary studies from Indonesia (e.g., Luthfiansyah & Fajarika, 2022; Zulfa, Rifai & Taufik, 2022) applied Civil 3D in real-world case studies, showing its ability to optimize road geometry in challenging terrains while ensuring compliance with local design standards. These studies suggest that Civil 3D is particularly effective in projects requiring dynamic updates and detailed 3D visualizations.

On the other hand, industry-focused evaluations highlight that MX Road is preferred in contexts where standardized outputs, contractual deliverables, and template-based designs are prioritized. According to professional evaluations (e.g., BK Engineering, n.d.), MX Road integrates seamlessly with IRC codes, allowing highway projects in India to be executed more efficiently with respect to compliance and documentation. While it may not offer the

same level of interactive 3D visualization as Civil 3D, MX Road's strength lies in its streamlined workflow for traditional road design processes, particularly in large-scale government projects where regulatory alignment is paramount.

Overall, the literature demonstrates that both software platforms are technically reliable for highway geometric design, yielding near-identical outputs for critical parameters such as minimum and maximum curve radii, superelevation, and transition length. The choice of tool often depends on project-specific priorities: Civil 3D excels in dynamic modeling, visualization, and BIM integration, making it ideal for projects emphasizing innovation and interdisciplinary collaboration, while MX Road is superior in template-driven design and regulatory compliance, particularly for projects under the jurisdiction of IRC standards. Importantly, researchers conclude that a dual-platform approach may offer the most robust solution, wherein Civil 3D's visualization and adaptability are complemented by MX Road's compliance and documentation efficiency, thereby ensuring both accuracy and practicality in modern highway projects.

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