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INTEGRATION OF TOPOGRAPHIC DATA INTO 3D CIVIL SOFTWARE AS ROAD DESIGN SUPPORT

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ABSTRACT

Accurate topographic mapping is a critical component in strategic planning and architectural design of road infrastructure, particularly in the assessment of optimal routing, evaluation of slope stability, and quantification of excavation volumes and landfill requirements. Advances in mapping technologies, such as geographic information systems (GIS), have significantly improved the resolution and precision of topographic data when compared to traditional methodologies. Utilizing Civil 3D software facilitates a faster and more effective approach to contour data analysis and visualization, enabling superior planning and informed decision-making. In addition, Civil 3D offers a number of functions, including assessment, volume cut and fill calculations, and drainage analysis, which have proven invaluable in the design of roads and related infrastructure. The researchers employed a feasibility methodology in their study, using Google Earth software as a tool to acquire satellite imagery, while Global Mapper was used for the extraction of coordinate data from each designated point; the processing of the resulting coordinates was performed in Autodesk Civil 3D for the design of a road spanning a total length of 970.70 kilometers. The purpose of this study was to formulate a more systematic and efficient methodology for the integration of topographic data to improve the accuracy and efficacy of 3D model-based road design. The proposed methodology includes analysis of state-of-the-art topographic mapping techniques, evaluation of data compatibility with 3D civil engineering software, and development of strategies for optimization of data formats and processing.

keywords : *Topography, Civil 3D, Road Planning, Contour Visualization, Gowa Regency*

1. PRELIMINARY

The rapid advancement of digital technologies has revolutionized the field of civil engineering, particularly in the design and planning of infrastructure projects such as roads[1]. Among the critical components of road design, topography plays a pivotal role in determining the alignment, gradient, and overall feasibility of a project. Accurate topographic data is essential for creating realistic 3D models, conducting precise simulations, and ensuring the structural integrity of road designs. However, despite the availability of advanced mapping technologies such as Geographic Information Systems (GIS)[2], the integration of topographic data into civil 3D software remains a complex and often inefficient process. This challenge underscores the need for innovative approaches to streamline the integration of topographic data into 3D civil design tools, thereby enhancing the accuracy and efficiency of road design projects.

In recent years, the adoption of 3D civil design software, such as AutoCAD Civil, has become increasingly prevalent in the infrastructure sector. These tools offer powerful capabilities for modeling, analysis, and visualization, enabling engineers to create more sustainable and cost-effective road designs. However, the full potential of these software solutions is often hindered by discrepancies in data formats, inaccuracies in topographic mapping, and the time-consuming nature of data integration processes. As infrastructure projects grow in scale and complexity, the demand for seamless integration of high-resolution topographic data into 3D design platforms has become more pressing. This research seeks to address these challenges by exploring methodologies for optimizing the integration of topographic data into civil 3D software, with the ultimate goal of improving the precision, efficiency, and overall quality of road design.

The integration of topographic data into the civil engineering design process has been extensively studied, with a focus on both traditional and modern mapping techniques. Conventional methods, such as terrestrial surveys, have long been the cornerstone of topographic data collection, providing reliable results but often being time-consuming and labor-intensive. In contrast, recent advances in remote sensing technologies, including Geographic Information Systems (GIS)[3], have revolutionized the field by enabling rapid, high-resolution data acquisition over large areas. These modern techniques have shown significant improvements in accuracy, efficiency, and cost-effectiveness, especially for large-scale infrastructure projects. However, despite their potential, the seamless integration of these sophisticated datasets into 3D civil design software remains an area that requires further exploration and optimization.

3D civil design software, such as AutoCAD Civil 3D and InfraWorks, have become indispensable tools for researchers, offering powerful capabilities for modeling, simulating, and analyzing road infrastructure projects. However, existing research also identifies persistent challenges in integrating topographic data into these systems, particularly regarding data compatibility, processing time, and maintaining data accuracy during conversion. While some studies have proposed solutions to address these issues, such as the development of automated data processing algorithms and standard data formats, a comprehensive framework for optimizing the integration of modern topographic data into 3D civil engineering software is lacking. This gap in the literature underscores the need for further research to bridge the gap between current mapping technologies and their practical applications in civil engineering design.

the utilization of Autodesk Civil 3D for road design facilitates the creation of precise three-dimensional models, thereby enabling planners to assess diverse design alternatives and enhance land utilization. The software significantly contributes to a streamlined and effective design process through functionalities such as surface analysis and soil volume computations. Furthermore, the synergy between Geographic Information Systems (GIS) and Autodesk Civil 3D enhances inter-team collaboration, promotes instantaneous data exchange, and expedites the decision-making process. Consequently, planners are afforded the opportunity to more readily discern potential challenges and viable solutions prior to the execution of projects, consequently mitigating unforeseen risks and expenses. The application of this technology additionally permits a comprehensive analysis of environmental impacts, ensuring that infrastructure planning incorporates considerations of sustainability and the conservation of natural resources. The deployment of ancillary maps is also essential as a fundamental component of the successful execution of geometric highway designs, necessitating thorough preparatory work by researchers before the actual design implementation. These maps encompass:

1. A fundamental cartographic illustration that delineates the characteristics of a specific area or design zone, extending from the initial point or origin of a roadway to the final point or intended destination of the infrastructure proposed for construction. (This cartographic illustration delineates the attributes of the area, encompassing religious sites, archaeological landmarks, natural reserves, cultural heritage sites, populated regions, watercourses, etc.).
2. Topographic maps, which function as representations of the spatial attributes of an area, characterized by the incorporation of contour lines that signify regions of uniform elevation.

2. METHODS

Location and Time

This investigation was executed in Belabori, situated within the Parangloe District of Gowa Regency, in the province of South Sulawesi.

Data Collection Techniques

a. Literature Study The literature study constitutes a methodological approach for the acquisition of data from a variety of bibliographic sources, encompassing books, digital repositories, scholarly articles, journals, and other pertinent linguistic materials that relate to the research endeavors undertaken.
b. Observation Observation is characterized as a method of data collection that entails systematic scrutiny, interpretation, and documentation of the behaviors and attributes of diverse phenomena.
c. Documentation Method This methodology for data collection is predicated on the utilization of documents as the primary source of data, serving to augment the research findings. The documents referred to may encompass written texts, films, and visual materials such as images or photographs.
d. Documentation The documentation study represents a data collection methodology that may take the form of written texts, illustrations, or the creative works of other individuals. The documentation available on this platform is provided in the format of images and photographs.

Design Planning

The methodologies employed encompass the preparatory phase, data acquisition from Google Earth, topographic map construction utilizing GIS software, and road geometric design through AutoCAD Civil 3D. The subsequent stages involved in the design process utilizing AutoCAD Civil 3D are as follows:

a. Acquisition of point data from Google Earth
b. Input of point data into the global mapper
c. Processing of point data within the global mapper[4]
d. Configuration of the coordinate system in Civil 3D
e. Input of point data
f. Creation of contours
g. Development of horizontal alignments [5]
h. Planning of superelevation
i. Formulation of vertical alignment

3. RESULTS AND DISCUSSION

Implementation Of Topographic Map Making

a. Determining Location Points Utilizing Google Earth

In the initial stage of this research endeavor, the process of data acquisition was undertaken through the utilization of Google Earth to determine the exact geographic coordinate points[6]. Subsequently, the necessary topographic data will be extracted and analyzed using appropriate software applications. Following the retrieval of the topographic data, the ensuing procedure entails the importation of the data into Global Mapper, subsequently integrating it into Civil 3D software for comprehensive analytical purposes. Upon successful data importation, users are empowered to initiate the creation of accurate surface models via the capabilities available within Civil 3D, which include surface generation and contour delineation. Moreover, users are presented with the opportunity to conduct further analyses by utilizing the measurement and modeling tools that have been provided, which encompass the calculation of drainage volume data, AC-WC volume, AC-BC volume, and the design of road geometry. Consequently, the researcher carried out the preliminary phase of data collection through the application of Google Earth software.

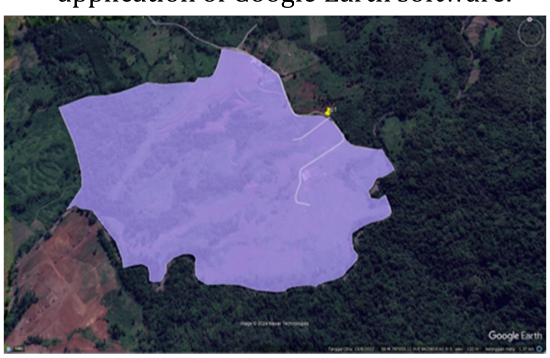

Figure 1. research location in Phinisi Hills (Google Earth)

b. Data retrieval on Google Earth

The procedure for data retrieval employing Google Earth[7] was carried out along a trajectory that encompasses a data extent of 26,722 meters, with designated latitude coordinates of 797530.95 m E and 9425403.14 m S within the framework of the Universal Transverse Mercator (UTM) zone 50S. Furthermore, to augment the accuracy of topographic mapping initiatives, the implementation of advanced data processing techniques is essential, such as the integration of Digital Elevation Models (DEM) which can be seamlessly incorporated with Civil 3D software[8]. By utilizing three-dimensional technology, the design of roadway infrastructure will not only achieve enhanced efficiency but will also produce a more genuine visual depiction of the existing geographic conditions. In addition, the incorporation of elements such as drainage systems and roadways within this model can facilitate environmental impact evaluations and the strategic development of sustainable infrastructure. The adoption of open Building Information Modeling (BIM) standards throughout this process promotes enhanced interdisciplinary collaboration, resulting in comprehensive and effective design solutions. The methodology utilized involves identifying the geographical location designated for examination, wherein the author solely approximates the points or routes to be outlined on Google Earth[9].

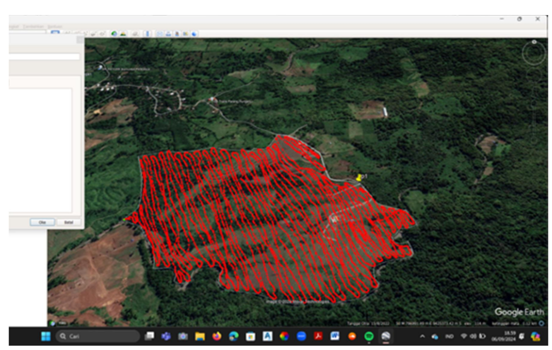

Figure 2. Path creation at the research location (Google Earth)

Global Mapper

Subsequently, location elevation data can be acquired by downloading the global mapper file, which entails selecting the desired file, followed by the options to export and subsequently choose the export vector/lidar format. The processing of data utilizing global mapper is conducted employing precise survey data in conjunction with contemporary mapping methodologies. Upon the completion of data exportation, the subsequent phase involves importing the file into Civil 3D software to initiate a more comprehensive road design procedure. This process ensures that the X, Y, Z point data is derived through the utilization of the global mapper.

Table 1 Contour point data (source: global mapper)

Titik Poin	Data Koordinat
P1	797506.790,9425656.500,180.583
P2	797510.041,9425652.265,180.1
P3	797513.281,9425647.985,179.647
P4	797517.562,9425643.731,179.29
P5	797520.757,9425640.975,179.108
P6	797524.981,9425639.709,179.188
P7	797529.212,9425637.022,179.123
P8	797531.336,9425634.262,178.946
P9	797531.158,9425657.162,181.466
P10	797526.878,9425661.346,181.785

The subsequent findings pertain to the triangulation methodology employed in the development of a Digital Terrain Model (DTM) derived from topographic measurement data points, which are sourced from Digital Elevation Model (DEM)[6] datasets in conjunction with Shapefile (SHP) data. This outcome elucidates a representation of the terrestrial surface that will serve as a foundational framework for subsequent analyses and the efficient design of road infrastructure. Moreover, this analysis will encompass a comprehensive assessment of slope gradients, drainage characteristics, and the selection of suitable materials to guarantee the sustainability and safety of the constructed roadway.

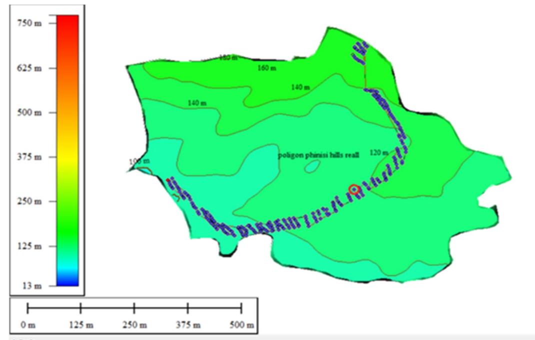

Figure 3. Coordinate points (Global Mapper)

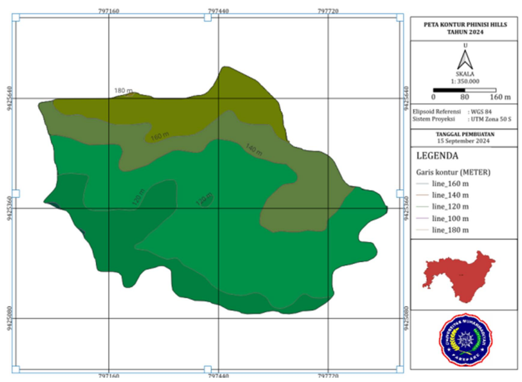

Figure 4 map layout (Global Mapper)

Autocad Civil 3D

a. Stages of Road Design Drawing

Geometric computations represent a crucial component of the geometric analysis pertaining to roadways, emphasizing the examination of their physical configuration, thus ensuring that they achieve the primary objective of enabling optimal traffic flow as a means of facilitating mobility access, which ultimately leads to the development of secure infrastructure. The ensuing geometric data pertains specifically to the roadways situated in Belabori, Parangloe District, Gowa Regency, in the South Sulawesi Province, covering the span from STA 0+000 to 0+971 km, and including critical details such as road width, gradient, turning radius, and elevation, all of which are essential for assuring the continuity and safety of road users, with calculations conforming to AASHTO standards as mandated by the Civil 3D software.

The initial step in the construction of roadways utilizing AutoCAD Civil 3D involves the formulation of alignment designs. The sequential steps required to determine road alignment are articulated as follows: First, prior to the initiation of the design phase, the researcher inputs the data points in a comma-separated values (CSV) file format, which has been obtained from the export generated in Global Mapper. Within the home tab, the researcher selects the Alignment menu to commence the preliminary phase and identify the specific type of design to be executed. Subsequently, it is essential to establish the design criteria for the proposed pathway, necessitating the creation of layers to distinctly differentiate the various components. A dialog box will appear within the layers menu; by clicking on "new," the researcher can designate the layer name and select the colors intended for the notation elements on the layer, after which selecting "ok" concludes the dialog and initiates the Alignment design process (path design). A toolbar will subsequently emerge, containing a menu exclusively dedicated to the creation of the path route: within this menu, the researcher selects the tangent-tangent option (inclusive of curves). The resultant output is illustrated below. To ensure that the spacing between the Station markers (STAs) is not inappropriately close, the STA distance may be adjusted by selecting one of the STAs, right-clicking, choosing "edit alignment labels," and subsequently substituting it with the standard distance in accordance with the STA labeling convention.

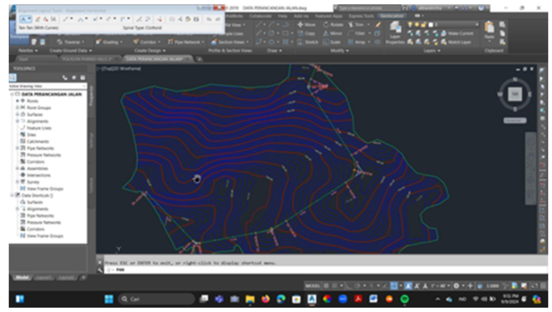

Figure 5. Results of determining alignment in Civil 3D (Source: Autodesk Civil 3D)

b. Vertical alignment design

Existing profile of planned alignment Existing profile obtained from the results of the planned horizontal alignment projection.

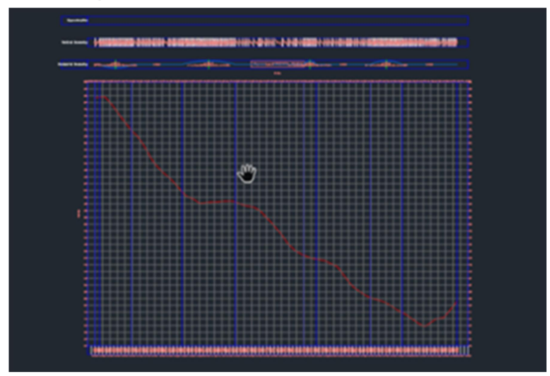

Figure 6 Existing profile of the alignment plan (Source: Autodesk Civil 3D)

Planned Alignment Projection Design Profile Based on the derived profile, the investigator executed the horizontal alignment projection design planning while adhering to the stipulated maximum gradient threshold of 10% in accordance with the regulations set forth by Bina Marga.

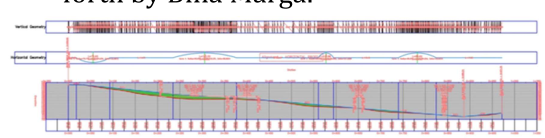

Figure 7 vertical alignment design profile (Source: Autodesk Civil 3D)

In AutoCAD Civil 3D 2019, it is imperative to first establish the assembly, offset alignment, and corridor within the road section. Subsequently, users are able to configure the necessary parameters to produce a cross-section that adheres to the requisite project specifications[10]. Thereafter, users may modify the visual attributes and intricate details of the cross-section to guarantee that all design components are cohesively integrated and comply with the predetermined standards .

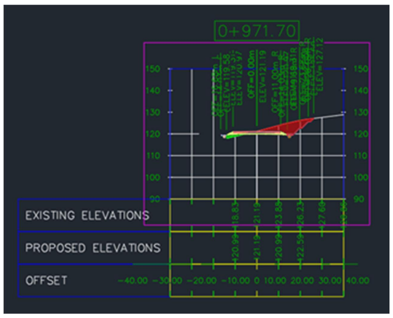

Figure 8. road cross-section (source: Autodesk Civil 3D)

The computations pertaining to cut and fill act as supplementary tools in the formulation of construction financial estimates. To elucidate the outcomes of these calculations, it is imperative to employ the Toolspace command to choose the Settings tab, subsequently expand Quantity Takeoff, then extend Quantity Takeoff Criteria, and finally select Cut and Fill. Thereafter, the researcher establishes the requisite parameters to yield the results that have been meticulously designed from the outset.

Table 2 Cut And Fill Volume Data (Source: Autodesk Civil 3D)

Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
0+000.00	0.00	27.94	0.00	0.00	0,00	0,00
0+020.00	0.00	66.59	0.00	948.44	0,00	948,44
0+040.00	0.00	37.02	0.00	1,017.89	0,00	1966,33
0+060.00	13.88	18.12	156.48	508.20	156,48	2474,53
0+080.00	45.28	10.87	666.68	238.88	823,16	2713,41
0+100.00	68.28	6.71	1,226.44	153.76	2049,60	2867,17
0+120.00	83.10	2.85	1,513.74	95.63	3563,34	2962,81
0+140.00	140.01	0.04	2,231.08	28.94	5794,42	2991,75
0+160.00	219.58	0.00	3,595.90	0.40	9390,32	2992,15
0+180.00	249.34	0.00	4,689.16	0.00	14079,47	2992,15
0+200.00	241.55	0.00	4,908.86	0.00	18988,34	2992,15
0+220.00	249.83	0.00	4,913.77	0.00	23902,11	2992,15
0+240.00	274.26	0.00	5,171.96	0.00	29074,07	2992,15
0+260.00	263.10	0.00	5,137.42	0.00	34211,50	2992,15
0+280.00	255.24	0.00	5,000.70	0.00	39212,19	2992,15
0+300.00	195.00	0.00	4,357.48	0.00	43569,67	2992,15
0+320.00	138.53	0.00	3,211.65	0.00	46781,32	2992,15
0+340.00	93.04	0.00	2,217.55	0.00	48998,87	2992,15
0+360.00	54.49	0.72	1,399.30	8.44	50398,18	3000.58
0+380.00	36.04	1.07	862.02	20.46	51260,19	3021,05
0+400.00	23.24	1.62	592.83	26.93	51853,02	3047,98
0+420.00	1.58	8.98	248.19	106.06	52101,21	3154,03
0+440.00	0.38	25.11	19.61	340.94	52120,82	3494,97
0+460.00	0.33	14.12	7.10	392.36	52127,93	3887,33
0+480.00	10.45	2.32	107.82	164.41	52235,75	4051,74
0+500.00	45.42	0.06	558.76	23.73	52794,50	4075,47
0+520.00	94.14	0.00	1,395.64	0.57	54190,15	4076,04
0+540.00	111.23	0.00	2,053.75	0.00	56243,90	4076,04
0+560.00	94.87	0.00	2,061.06	0.00	58304,96	4076,04
0+580.00	70.29	0.28	1,733.40	2.28	60038,36	4078,32
0+600.00	26.04	1.17	1,007.04	12.66	61045,39	4090,99
0+620.00	0.33	16.43	263.72	176.01	61309,11	4267,00
0+640.00	0.00	43.63	3.34	600.60	61312,45	4867,60
0+660.00	0.00	36.88	0.01	805.08	61312,46	5672,68
0+680.00	19.38	5.65	193.80	425.24	61506,26	6097,91
0+700.00	43.45	2.32	628.34	79.70	62134,60	6177,61
0+720.00	40.69	1.80	841.46	41.22	62976,06	6218,83
0+740.00	27.06	2.82	677.50	46.17	63653,56	6264,99
0+760.00	14.25	10.41	447.40	111.68	64100,96	6376,68
0+780.00	0.00	28.58	160.84	357.06	64261,80	6733,74
0+800.00	0.00	41.00	0.02	676.82	64261,83	7410,56
0+820.00	0.00	43.57	0.00	853.46	64261,83	8264,02
0+840.00	0.00	51.57	0.00	956.86	64261,83	9220,88
0+860.00	0.00	44.25	0.00	958.23	64261,83	10179,11
0+880.00	0.00	55.92	0.00	1,001.67	64261,83	11180,78
0+900.00	0.24	51.89	2.41	1,078.11	64264,23	12258,89
0+920.00	8.02	48.39	82.57	1,002.79	64346,80	13261,68
0+940.00	33.57	53.87	415.91	1,022.57	64762,71	14284,25
0+960.00	19.39	80.74	529.59	1,346.10	65292,30	15630,35
0+971.70	7.37	92.80	156.44	1,014.93	65448,75	16645,27

Geospatial imagery representation of transportation infrastructure design Derived from the road design data that has been meticulously developed, it is now feasible to exhibit this information in geospatial format utilizing the Autocad Civil 3D software that has been made available.

Figure 9. Road Design Geolocation Results (source: Autodesk Civil 3D)

4. CONCLUSION

The significance of precise topographic mapping is paramount in facilitating an effective and efficient road design process, alongside the incorporation of high-quality data into Civil 3D software to enhance the caliber of design outcomes. Consequently, the researchers derived findings indicating that the amalgamation of data acquired via GIS software with Civil 3D can be executed, as evidenced by the researchers' presentation of road design outcomes that can exhibit horizontal alignment data, vertical alignment, corridors, and cut and fill volumes correlated to geolocation, utilizing initial data sourced from Google Earth. In the present investigation, the researchers gathered data pertaining to the study locale, wherein they identified the challenges posed by the terrain at the research site, characterized by notably extreme contour configurations. The steep elevation data is discernible from the contour data, which indicates the apex within the research area, marked at an elevation of approximately 182 meters, while the lowest elevation recorded by the researchers was around 80 meters, thereby illustrating that the slope at the research site is considerably extreme.

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