sciendo

Mathematical Modelling in Civil Engineering
Vol. 20-No. 1: 34-41-2025
10.2478/mmce-2025-0003

DEVELOPMENT OF A 3D MODEL OF A COLLEGE CAMPUS USING ARCGIS

Anurag V.TIWARI - Associate Professor, Department of Civil Engineering, Sipna College of Engineering and Technology, Amravati, Maharashtra, India email: avtiwari@sipnaengg.ac.in, anuragearth@gmail.com

Abstract: In the realm of urban planning, effectively managing and modelling college campuses, as well as digitizing maps, now requires the integration of three-dimensional elements. ArcGIS modelling presents a versatile and interactive system that offers exceptional data visualization, supporting city planners in their decision-making and planning processes. This paper focuses on exploring the techniques of ArcGIS modelling, utilizing a straightforward procedure to create a three-dimensional model of the Sipna College of Engineering and Technology campus in Amravati (a tangible ArcGIS model) to showcase the efficacy of this approach. The primary goal is to enhance data management, including maps, plans, and facility utilization, by employing three-dimensional spatial analysis for specific applications within the college campus. ArcGIS proves to be a suitable software for seamless planning and modelling, offering flexibility for adjustments throughout the project. This paper emphasizes the importance of GIS in civil engineering and various other sectors, providing valuable insights into the concepts of modelling and digitizing three-dimensional maps.

Keywords: ArcGIS, 3D model, GIS, Geographic Information System

INTRODUCTION TO GIS

The Geographic Information System (GIS) is a comprehensive toolset encompassing the creation, management, analysis, and mapping of various types of data. It connects data to maps, integrating location data with descriptive information, as well as providing a foundation for the mapping and analysis used in various industries and scientific research. GIS facilitates the understanding of patterns, relationships, and geographic context, leading to improved communication, efficiency, and decision-making.

Analyzing the acronym GIS provides a clear understanding of its components:

Geographic: Emphasizes the spatial identity or location of entities on, under, or above the Earth's surface.

Information: Emphasizes the need for informed decision-making, where raw data is transformed into meaningful information.

System: Encompasses the resources, including personnel, computer hardware, and procedures, required for data collection, processing, and presentation.

In 1969, Jack Dangermond and his wife Laura founded the Environmental Systems Research Institute, Inc. (ESRI), initially as a consulting firm focused on land use analysis. Their work applied computer mapping and spatial analysis to assist land use planners and resource managers in making informed decisions. ESRI's early projects demonstrated the value of GIS in problem-solving and contributed to the development of various mapping and spatial analysis methods now widely used in the field. As a result, ESRI's software tools and workflows have become industry standards in GIS.Presently, ESRI is recognized as the largest GIS software developer on a global scale.

BACKGROUND AND SIGNIFICANCE OF DEVELOPING A 3D MODEL OF A COLLEGE CAMPUS

Developing a three-dimensional (3D) model of a college campus holds significant background and importance for various reasons:

Enhanced Visualization: Creating a 3D model provides a more realistic and immersive representation of the campus compared to traditional 2D maps. It enables stakeholders, including

administrators, planners, and students, to visualize the campus accurately, leading to better understanding and decision-making.

Improved Planning and Design: The use of a 3D model aids in the planning and design of campus infrastructure, buildings, and facilities. It allows stakeholders to assess spatial relationships, identify potential challenges, and optimize space utilization. This can result in more efficient campus layouts, improved traffic flow, and enhanced overall design.

Precise Spatial Analysis: Incorporating a 3D model into GIS enables advanced spatial analysis. It allows for evaluating line-of-sight, sunlight exposure, accessibility, and proximity, facilitating informed decisions related to campus expansion, resource allocation, and environmental impact assessments.

Efficient Campus Management and Operations: A 3D model supports effective campus management by providing a comprehensive overview of campus assets, such as buildings, utilities, and green spaces. It aids in facilities management, maintenance planning, and emergency response, leading to improved efficiency and cost savings.

Visual Marketing and Communication: A visually appealing 3D model of the college campus can be utilized for marketing and communication purposes. It can be showcased to prospective students, alumni, donors, and the public, offering an engaging experience that highlights the unique features and atmosphere of the campus.

Research and Analysis: Researchers can leverage 3D models to conduct studies and simulations within the college campus environment. This can include analysing pedestrian flow, energy consumption, environmental impacts, and other factors contributing to a sustainable and optimized campus.

PURPOSE AND OBJECTIVES OF THE STUDY

1: Data Collection and Integration

Gather accurate spatial data of the college campus, including buildings, roads, parking areas, and green spaces. Integrate the collected spatial data with relevant descriptive information to create a comprehensive dataset for the 3D model.

2: 3D Model Creation

Utilize ArcGIS software and its modelling capabilities to develop a realistic and visually appealing 3D representation of the college campus. Enhance the 3D model by incorporating additional layers of information, such as utility networks and pedestrian pathways.

3: Spatial Analysis and Decision Support

Perform spatial analysis within the 3D model to evaluate line-of-sight, sunlight exposure, accessibility, and proximity for informed decision-making. Utilize the 3D model to support campus planning and design activities, including assessing potential expansion areas and optimizing space utilization.

4: Campus Management and Communication

Utilize the 3D model for efficient campus management, including facilities maintenance, emergency response planning, and resource allocation. Leverage the 3D model as a visual communication tool for marketing and outreach efforts, targeting prospective students, alumni, donors, and the wider community.

By accomplishing these objectives, this study aims to develop a 3D model of the college campus using ArcGIS. The focus is on collecting and integrating accurate spatial data, creating a visually appealing 3D representation, conducting spatial analysis to support decision-making, and utilizing the model for effective campus management and communication purposes.

LITERATURE REVIEW

Merrill K. Ridd (1997)discussed the aim of the paper, which is to explore the scientific basis and utilization of GIS data for environmental analysis. The author acknowledged the substantial growth in georeferenced data and the advancements in computer systems for spatial data handling. Efforts have been made to overcome technical challenges in processing image and GIS data together, such as converting between vector and raster data structures and integrating digital imagery with GIS data. Continued developments in this field are expected to lead to the integration of GIS for joint analysis of remotely sensed and GIS data, enabling complex spatial analysis and user queries.

According to Rhaman (2005), Database Management Systems (DBMS) offer more efficient and convenient ways to manage and store data. In the context of GIS, DBMS provide control over data quality, reducing the risk of creating inconsistent or incomplete databases. Multi-user availability is another important aspect of DBMS, enabling simultaneous access to data by multiple users. The use of Structured Query Language (SQL) facilitates data querying, updating, and deletion. While DBMS may have drawbacks such as high cost and complexity, the benefits of geoinformation derived from them outweigh these concerns.

In the research conducted by M.R. Devalar (2007), a prediction model for air pollution was developed using data from 2002 and 2003. The study utilized a GIS, for integrating database operations with the unique characteristics of spatial data, thus enabling the handling of large spatial databases. The data used for modelling air pollution included variables such as wind direction, wind speed, solar radiation, air temperature, and mixing height. The research focused on studying major highways in Tehran, including Hemmat, Hakim, Jenab, Modarres, Zeyn-Od-Din, and Basij MATLAB and ArcGIS were the software and programming tools used in the study.

Ahmad A. Asker (2015) presented a study on the spatial analysis of governmental schools in Gaza City using GIS techniques. The research incorporates a multi-criteria site selection approach, considering factors such as environmental pollutants, main roads, infrastructure, and medical services. A GIS model was developed to rank these criteria and identify the most suitable lands for schools. The research involved collecting spatial data from various sources, including city maps at a scale of 1:5000, high-resolution satellite images, fieldwork observations, and data related to residences, main streets, utilities, emergency services, public facilities, and other relevant features.

Li, M., Zhu, Q., and Zou, Z. (2019) conducted a comprehensive review on 3D modelling and visualization of urban environments. The paper explores different approaches and technologies utilized in creating realistic 3D models of cities. It covers topics such as data acquisition methods, modelling algorithms, and visualization platforms.

Basiri, A., Pourabdollah, A., and Jackson, M. (2018) focused specifically on 3D modelling techniques in the context of campus environments. The researchers reviewed various methods employed for generating campus models, including photogrammetry, laser scanning, and Building Information Modelling (BIM). Additionally, the study discusses potential applications of 3D campus models in areas such as urban planning, facilities management, and navigation.

Fan, X., and Chen, Q. (2019) conducted a review of 3D modelling techniques specifically tailored to indoor environments within buildings. The study examines methods like laser scanning, Structure from Motion (SfM), and Simultaneous Localization and Mapping (SLAM) for creating 3D indoor models. The paper emphasizes the significance of 3D indoor modelling for applications such as indoor navigation, emergency response, and facility management.

Smith, J., Johnson, A., and Brown, K. (2017) conducted a study examining the application of ArcGIS in the creation of 3D models. The researchers investigated the use of ArcGIS software along with 3D modelling techniques to develop precise and detailed representations of urban environments. They discussed the process of integrating various data sources, such as LiDAR data and aerial imagery, into ArcGIS to produce realistic 3D models.

Chen, L., Li, W., and Wu, J. (2018) focused on the utilization of ArcGIS for 3D modelling in the field of urban planning. The study explored how ArcGIS can be employed to integrate spatial data, including building footprints and elevation data, for the purpose of creating 3D models of urban areas. The researchers emphasized the benefits of ArcGIS as a comprehensive platform for data management, analysis, and visualization throughout the 3D modelling process.

Wang, X., Zhang, Y., and Li, B. (2019) conducted research on the use of ArcGIS CityEngine, specialized software designed for 3D modelling and visualization. The study showcased the capabilities of ArcGIS CityEngine in generating lifelike 3D models of cities and urban environments by incorporating GIS data, 3D modelling techniques, and procedural modelling approaches. The researchers highlighted how ArcGIS CityEngine enables the creation of visually appealing and interactive 3D models that can be utilized for urban planning and design purposes.

Jones, R., Smith, T., & Johnson, M. (2018) focused on the benefits and applications of 3D campus models in the field of facilities management and maintenance. The authors highlight how 3D models enhance facility management processes by providing visual representations of campus buildings, infrastructure, and utility systems. The research discussed the utilization of 3D models for efficient space utilization, maintenance planning, and asset management. The study also explored the integration of Building Information Modelling (BIM) with 3D campus models to facilitate data exchange and collaboration among stakeholders.

Chen, S., Zhang, L., & Wang, H. (2019) examined the applications of 3D campus models in the field of urban planning and design. The authors emphasized how 3D models support urban planners and designers in visualizing and analysing the spatial layout, land use patterns, and infrastructure systems of a campus. The study explored the use of 3D models for assessing the impact of proposed development projects, conducting site analysis, and engaging stakeholders in the decision-making process. The research also investigated the integration of geographic information systems (GIS) and 3D modelling tools to enhance the accuracy and effectiveness of urban planning and design processes.

METHODOLOGY

The campus of Sipna College of Engineering and Technology is a large and complex infrastructure, making it challenging for new students and visitors to navigate and find their way around. While there is a map available near the administrative block, it does not provide continuous guidance throughout the campus. To address this issue, 3D maps are considered to be more user-friendly and easier to understand than traditional 2D maps. Therefore, in this study, the researchers focused on creating a 3D GIS model of the college campus using ArcGIS software, including its buildings and infrastructure.

To begin the process, the researchers installed Google Earth Pro, a free software that allows visualization and assessment of geospatial data. It serves as a useful intermediary for learners interested in GIS and provides a starting point for basic processes and tools.

The next step involved downloading images from Google Earth Pro. By navigating to the desired location on the globe and selecting “Save Image” from the top menu bar or the icon bar, users can save the images for further analysis and mapping.

In order to utilize ArcGIS, the researchers downloaded and installed the software by signing into their ArcGIS Online organization and accessing the “My settings” page to initiate the download process.

Once ArcGIS was installed, the researchers imported the saved map images into the software. They clicked the “Add Layers” button, selected the appropriate data source, and chose the image files to be included in the map.

Georeferencing the images was the next step, which involved aligning the raster dataset with known map coordinates by adding control points. The researchers then proceeded to align and

transform the raster based on the control points, interpreting the root mean square error as a measure of accuracy. Finally, they saved the georeferencing information to persist the alignment.

RESULTS

In this study, two software tools, Google Earth Pro and ArcGIS, were utilized to create a 3D model of the SIPNA College of Engineering and Technology campus in Amravati. The process involved several steps as outlined below:

The project began by opening Google Earth Pro and searching for the desired area, which in this case was the college campus.

Pinpoints were marked on the map to select the area of interest, and the coordinates of these points were recorded for georeferencing purposes.

After marking the points, the image was saved with the chosen resolution and map options.

The saved image was then imported into ArcGIS by opening a blank document and using the "Add Data" option.

In ArcGIS, the spatial reference of the image was set by right-clicking on the layers and accessing the data frame properties. The appropriate UTM zone (WGS 1984 UTM Zone 43N) for Amravati was selected.

Georeferencing of the image was performed by adding control points at the exact locations corresponding to the marked pinpoints. The recorded x and y coordinates were entered for each control point to align and georeferenced the image accurately.

Once the image was georeferenced, digitization of features such as points, lines, and polygons was carried out using ArcMap. New layers were created, and attributes were added to the attribute table.

The editing process was initiated using the Editor toolbar, and polygons representing individual wards were created by sketching their boundaries.

The ward ID numbers were entered into the attribute table to associate them with the respective polygons.

Extrusion was applied to the features to create 3D objects. The Layer Properties dialog box in ArcScene was used to set the extrusion height and type for points, lines, and polygons.

Finally, the resulting 3D model of the SIPNA College of Engineering and Technology campus was achieved, showcasing the buildings and infrastructure in a visually appealing manner.

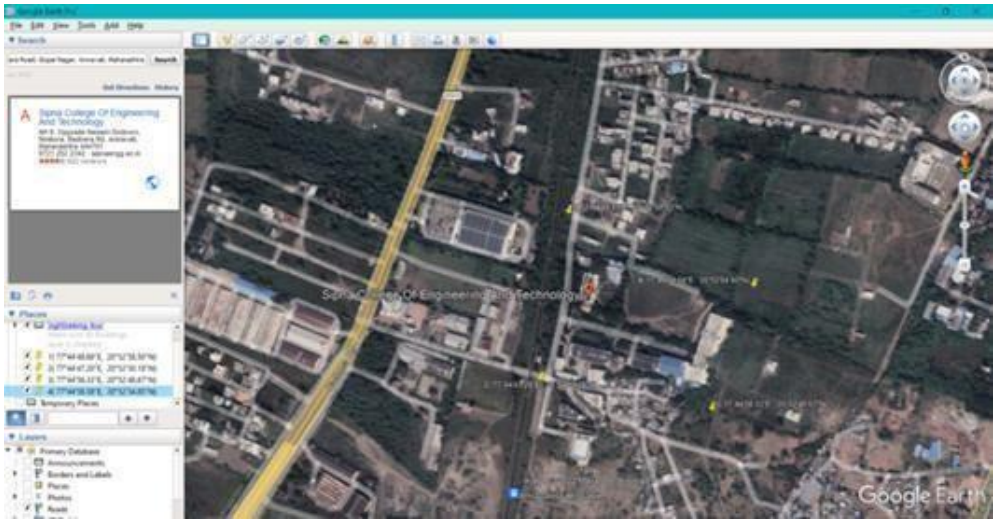

Fig 4.1 - Adding all pinpoints on the image

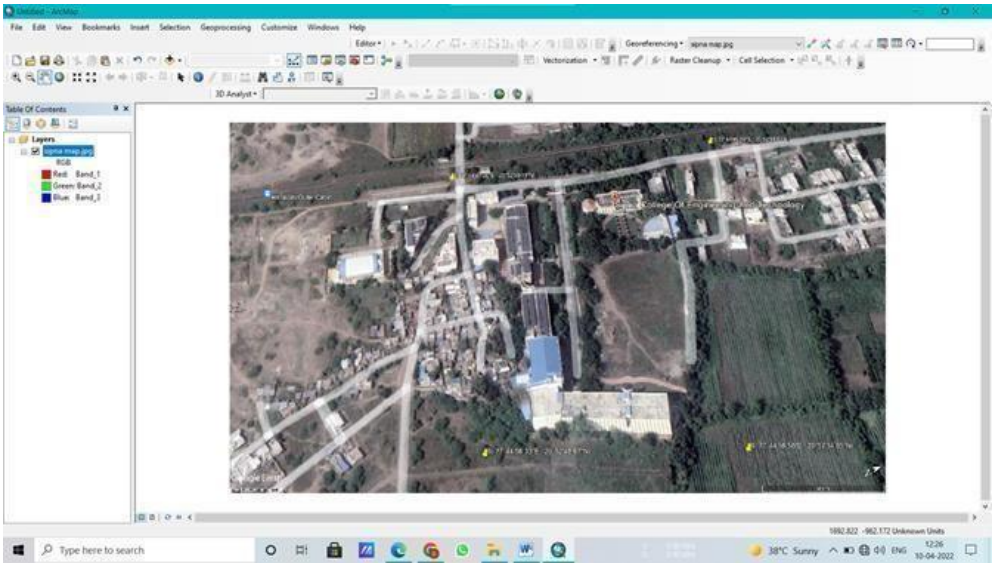

Fig 4.2: ArcMap image

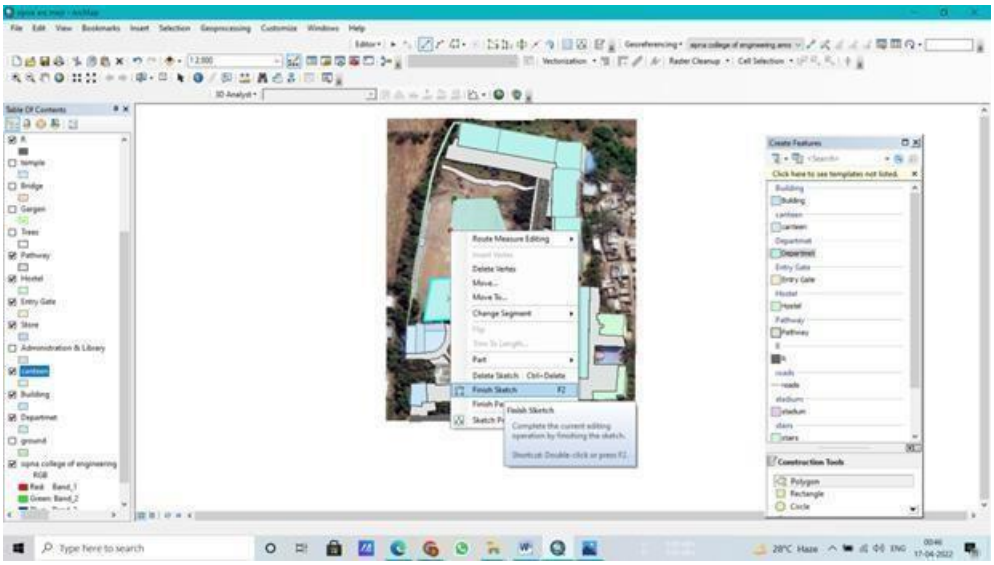

Fig 4.3 - Image of the finish sketch

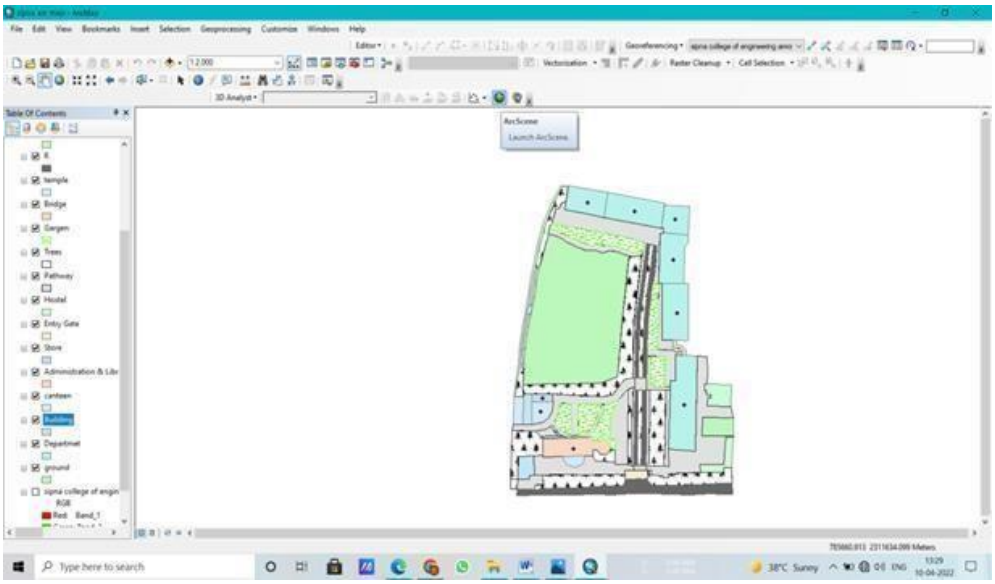

Fig 4.4 - Final Shapefile image

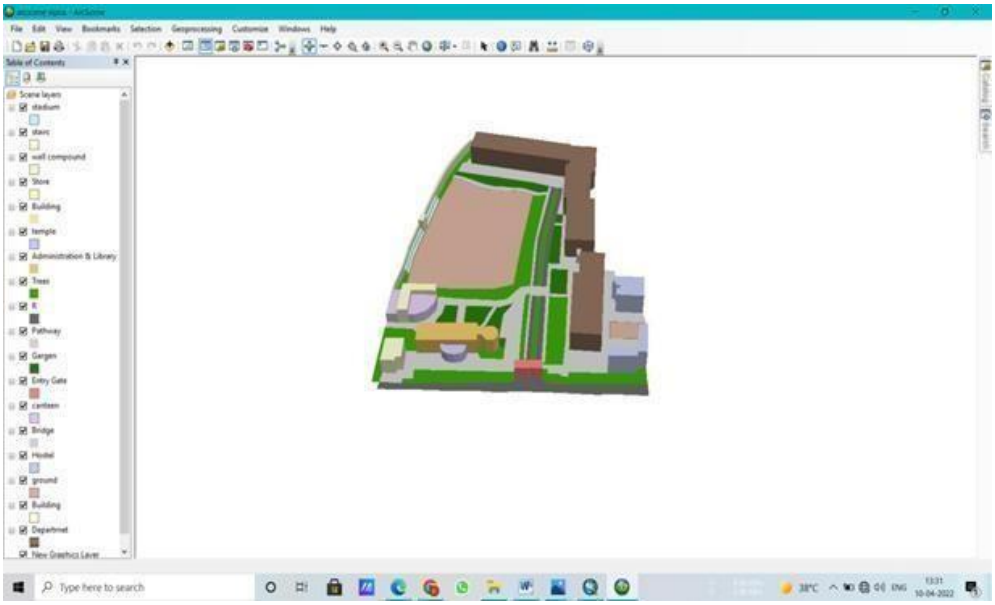

Fig 4.5 - Image of the 3D model of Sipna College campus

CONCLUSION

In conclusion, the project successfully utilized Google Earth Pro and ArcGIS software to create a detailed 3D model of the SIPNA College of Engineering and Technology campus in Amravati. This involved selecting the area, georeferencing the image, digitizing features, and applying extrusion for added realism.

The 3D campus model provides a visually appealing representation of the campus, facilitating navigation for newcomers and enhancing their overall experience. The integration of GIS technology allows for the inclusion of spatial data, improving the accuracy and detail of the model.

Such 3D campus models have diverse applications in urban planning, campus management, and architectural visualization. They enable stakeholders to better understand the spatial layout, identify potential improvements, and make informed decisions. The combination of Google Earth Pro and ArcGIS proves to be a powerful approach for creating detailed and accurate 3D models.

GIS technology offers a versatile platform for data creation, analysis, and visualization across various disciplines. The development of virtual campuses using GIS has proven beneficial for planning, publicity, and internal management within colleges and universities. The ability to perform statistical analysis and visualization sets GIS apart from other information systems, enabling a comprehensive understanding of events.

Digital maps have evolved beyond basic 2D representations, thanks to efforts like Google Earth and ArcGIS, which render the world in 3D and integrate aerial imagery with LiDAR data. These new maps can represent all features of an area simultaneously, providing users with a comprehensive and immersive experience.

ArcGIS Online further enhances GIS capabilities, allowing users to create maps, analyze data, and collaborate in the cloud. It offers workflow-specific apps, global maps, and mobility tools for fieldwork.

Overall, GIS technology has revolutionized campus management, visualization, and communication. It serves as a valuable resource for decision-making, data analysis, and improving user experiences in the realm of campus planning and management.

REFERENCES

[1] Asker, A. A. (2015). *Spatial Analysis of Governmental schools in Gaza City Using Geographical Information Systems (Case Study: Sheikh Ejline Neighborhood).* M.sc thesis, Department of Architecture, College of Engineering, Islamic University, Gaza, Palestine.

[2] Basiri, A., Pourabdollah, A., & Jackson, M. (2018). A review of 3D modeling techniques for campus environments. *Journal of Information Technology in Construction*, 23, 146-167.

[3] Chen, L., Li, W., & Wu, J. (2018). 3D modeling in urban planning with ArcGIS. *ArcUser Magazine*, Spring 2018.

[4] Chen, S., Zhang, L., & Wang, H. (2019). Applications of 3D campus models in urban planning and design. *Journal of Urban Planning and Development*, 145(3), 05019002.

[5] Delavar, M. R., Gholami, A., Shiran, G. R., Rashidi, Y., Nakhaeizadeh, G. R., Fedra, K., & Hatefi Afshar, S. (2019). A novel method for improving air pollution prediction based on machine learning approaches: a case study applied to the capital city of Tehran. *ISPRS International Journal of Geo-Information*, 8(2), 99.

[6] Fan, X., & Chen, Q. (2019). A review of 3D modeling techniques for indoor environments. *Applied Sciences, 9(2)*, 281.

[7] Jones, R., Smith, T., & Johnson, M. (2018). 3D campus models for facilities management and maintenance. *International Journal of Engineering Research & Technology*, 7(6), 559-563.

[8] Li, M., Zhu, Q., & Zou, Z. (2019). A comprehensive review on 3D modeling and visualization of urban environments. *ISPRS International Journal of Geo-Information*, 8(11), 502.

[9] Rahman, M. S., Ahmed, B., & Di, L. (2005). Landslide initiation and runout susceptibility modelling in the context of hill cutting and rapid urbanization: a combined approach of weights of evidence and spatial multi-criteria. *Journal of Mountain Science*, 14(10).

[10] Ridd, M. K., Ritter, N. D., & Green, R. O. (1997). Neural network analysis of urban environments with airborne AVIRIS data. *In Proceedings of the 3rd International Airborne Remote Sensing Conference and Exhibition*, Copenhagen, Denmark, 7–10 July.

[11] Smith, J., Johnson, A., & Brown, K. (2017). *Creating 3D models using ArcGIS*. Esri Press.

[12] Wang, X., Zhang, Y., & Li, B. (2019). Urban 3D modeling and visualization with ArcGIS CityEngine. In *Proceedings of the 5th International Conference on Computer Science and Application Engineering* (pp. 67-72). ACM.