International Journal of Functional Research in Science and Engineering
e-ISSN: 2814-0923
www.ijfrse.com
Volume 1; Issue 2; September 2023; Page No. 32-39.

APPLICATION OF 3D GEOSPATIAL INFORMATION TECHNOLOGY IN ROAD CONSTRUCTION IN EDO STATE, NIGERIA

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Abstract
The growing trend of the 4th Industrial Revolution has propelled the application of numerous technological approaches in the construction industry. Building information modeling (BIM), laser scanners, unmanned aerial vehicles (UAVs), and automated construction equipment are increasingly incorporated in the sector. The present study examined the application of 3D geospatial information technology in road construction in Edo state, Nigeria. The Global Navigation Satellite System (GNSS), static light detection and ranging (LiDAR), and UAV LiDAR were used to build 3D geospatial information of the study area effectively, and 3D designs were generated using the acquired data. A 3D design reflecting the actual terrain was created, and various sensors were installed on the construction equipment to conduct experiments on construction automation. The study concludes that construction automation has the advantage of knowing the design values and the site condition in real-time. The finding has implications for improving construction productivity for roads and many other constructions works.

Keywords: 3D, geospatial information technology, road construction

Introduction

A technology revolution that completely changes how work is conducted is occurring in the global industrial ecology. The transformation is unlike anything humans have ever encountered regarding magnitude, scope, and intricacy. While its development is unknown, the political actors, public and corporate sectors, academia, and civil society must work together to develop an integrated and comprehensive response. With the popularity of artificial intelligence, big data, and the Internet of Things, the world of work nowadays is featured with technological advancement, open innovation, and collaboration. This happens mainly in the manufacturing sectors, the Industrial 4.0 or the 4th Industrial Revolution (Yun et al., 2021)

The trend refers to the technological transformation society is undergoing in the 21st Century (Ross & Maynard, 2021) and the digitization of the manufacturing industry. It is fueled by disruptive trends such as the growth of data and connectivity, human-machine interaction, analytics, and advancements in robotics. The First Industrial Revolution utilized water and steam power to automate production. Electricity was employed by the second to facilitate mass production. The third is automated production using electronics and information technologies. The Third Industrial Transformation, the digital revolution that has been taking place since the middle of the previous century, is now giving way to a Fourth Industrial Revolution (Amadi-Echendu, 2021; Herreweghe, 2015; Kim, 2020; Kurfuss, 2014; Mendoza Valencia et al., 2019; Parliament of The Republic of South Africa, 2019; Saidi, 2022; Thabisile et al., 2022). The current revolution describes a technology fusion that obfuscates the boundaries between the physical, digital, and biological domains, which is what makes it unique.

Nigeria's diverse construction industry ranges from residential, industrial, and commercial projects to infrastructure construction. More important is the industry's contribution to the country's Gross Domestic Profit (GDP). Change is imminent in the construction industry, which has, in many ways, stayed relatively stagnant during recent decades. Performance needs to be enhanced, and the sector needs to be introduced to a new paradigm. In the meantime, the digital revolution has achieved much in the manufacturing and service industries. For example, the evolution of digitalization has enabled novel approaches to addressing construction challenges. Building Information Modelling (BIM) and the Internet of Things (IoT) are transforming design, construction, and operation in the construction environment (Succar & Kassem, 2015). Also, augmented reality, unmanned aerial vehicles (UAVs), 3D laser scanning, robotic engineering, and more advanced building materials have begun to be applied in the construction ecology.

Productivity opportunities arise by exploiting these digital advancements (Succar & Kassem, 2015). In addition, a production process oriented toward manufacturing has the potential to enhance productivity.

Nigeria attaches increasing importance to using environmentally friendly technologies in developing its road infrastructure. Many construction sites increasingly utilize BIM, laser scanners, UAVs, and automated equipment. However, there has not been enough research done on the application and analysis of 3D geospatial information in the construction industry in Nigeria. Thus, the present study examined the application of 3D geospatial information technology in road construction in Edo State, Nigeria.

Materials and Method

In this study, a road construction site located in Esan South East, Edo State, Nigeria, was selected as a study area to conduct experiments using 3D geospatial information technology for road construction. Figure 2 shows the study area. Surveying was needed for the 3D design of the study area, and data acquisition was performed.

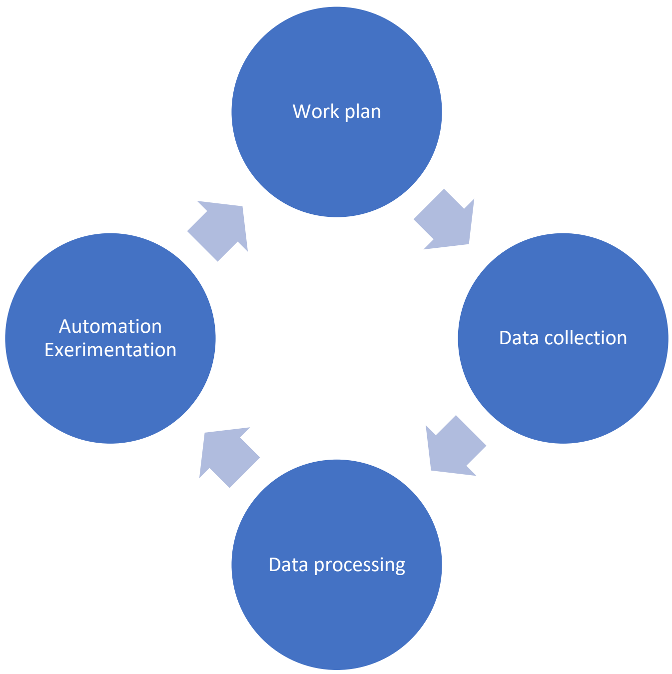

Fig. 1. Work Chart.

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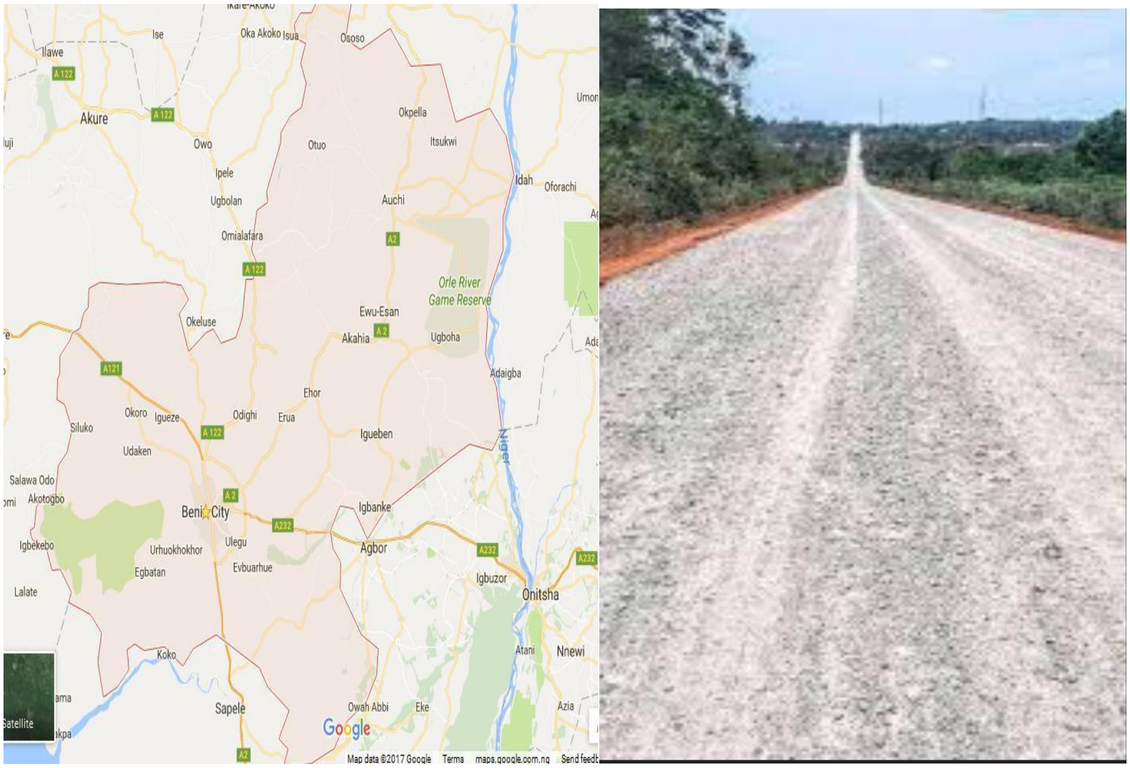

Fig. 2. Study area.

GNSS and two types of scanners were used for surveying to obtain geospatial information for the area. GNSS was used for reference point surveying and data calibration, static light detection and ranging (LiDAR) was used for 3D laser scanning, and UAV LiDAR was used for data acquisition. Data acquired by static LiDAR were used for georeferencing the data obtained by UAV LiDAR.

Table 1 shows the Geophysical Digital Survey Equipment.

The Global Navigation Satellite System GNSS	
The static LiDAR scanner	
The UAV LiDAR Equipment	

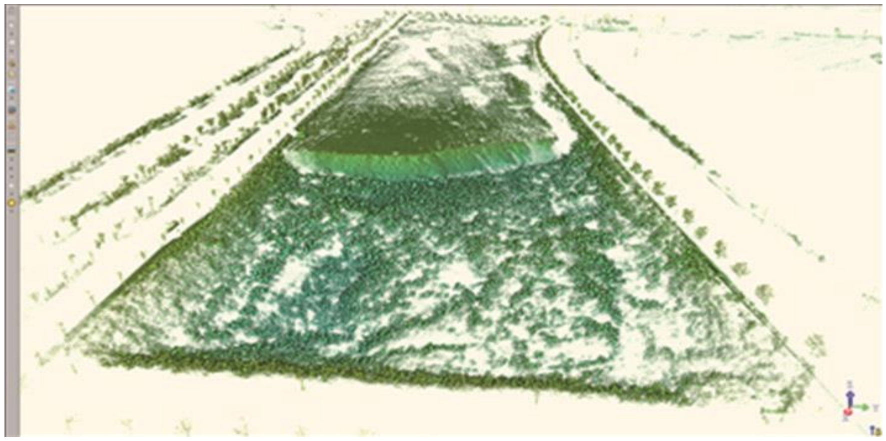

Fig. 3. Static LiDAR data.

Static LiDAR data provide very accurate results because reference point data are used. However, as shown in Fig. 3, some areas have no data. Data acquisition must be performed at many points to overcome the lack of data, achieved using UAV LiDAR in this study. UAV LiDAR has a lower data accuracy than static LiDAR but has a high efficiency for data acquisition. To acquire data using UAV LiDAR, a mission plan for the study area was created, and data acquisition was performed. Data collection using UAV LiDAR took about 6 min, with a GNSS base station installed on the ground to improve accuracy, and data were logged at intervals. The coordinates of the base station were used for data processing. Finally, registration was performed using the static LiDAR data. Figure 4 shows the data acquired by UAV LiDAR.

Data Processing and Analysis

Ground data were generated using UAV LiDAR data for use in the design. The land and vegetation were classified using Trimble Business Center (TBC) software. Ground was classified

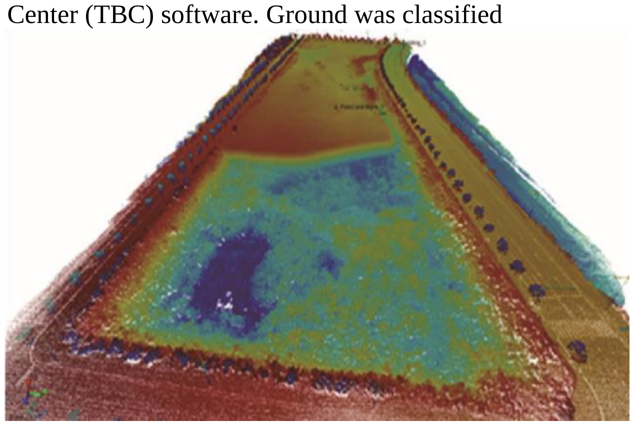

Fig. 4. (Color online) UAV LiDAR data.

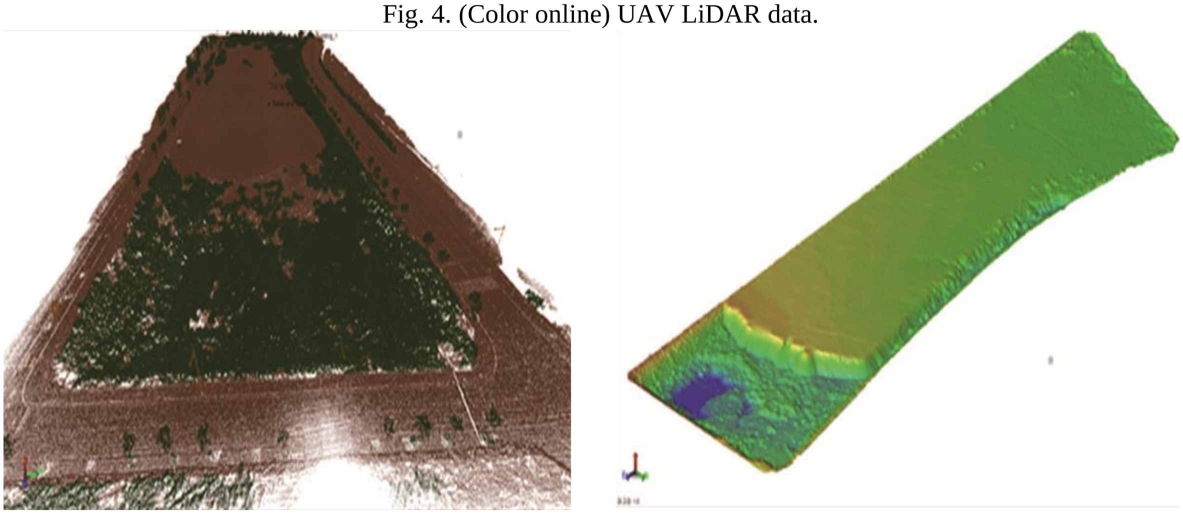

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Fig. 5. Classification result. Fig. 6. Mesh data for ground.

as brown and other (unnecessary) objects were classified as green. Through this classification, the data about the ground were generated, and mesh data were created to use the ground data for design. Since LiDAR data are point-cloud-type data, it is difficult to use them for design directly. Figure 5 shows the classification result, and Fig. 6 shows mesh data for the ground. 3D design data must be applied to construction equipment in preparation for automated construction. For data preparation, the data obtained through static LiDAR and UAV LiDAR were registered and georeferenced, and accuracy was checked by comparison with GNSS survey results.

Lines were entered to generate a 3D design for road construction. A vertical line and a plane line for the linear road were inserted. The procedure for inputting road characteristics is illustrated in Figure 8. After the alignment was input, a template representing the shape of the road for the plane was input every 20 meters so that the design values could be described in three dimensions. Some of the road templates are displayed in Figure 9. Through input to the road parameter and template, a 3D design like the actual terrain of the target site was created. Figure 10 shows the completed 3D design, comprising data for two roads, one built by traditional road construction and the other made by automated construction. Abnormalities were checked, and the earthwork quantity was calculated using the 3D design created through the study. Figure 11 shows a design check, and Fig. 12 shows the calculation of the amount of earthwork.

Evaluating the Efficiency of Construction Automation

To compare the traditional road construction method with the automated process, a road with a distance of 260 m was constructed by each way. The construction equipment used was an excavator, a dozer, a grader, and a compactor. To evaluate automated road construction,

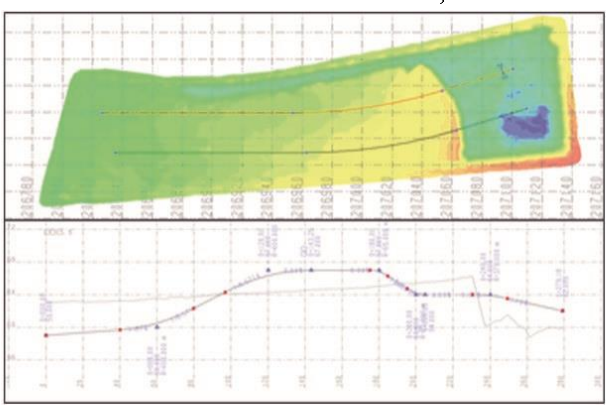

Fig. 8. Process of inputting road parameters

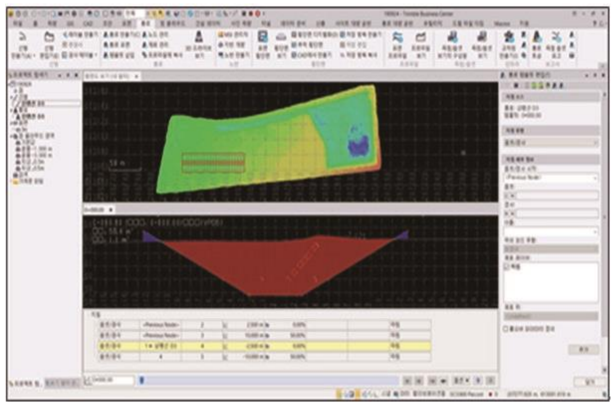

Fig. 9. Road template.

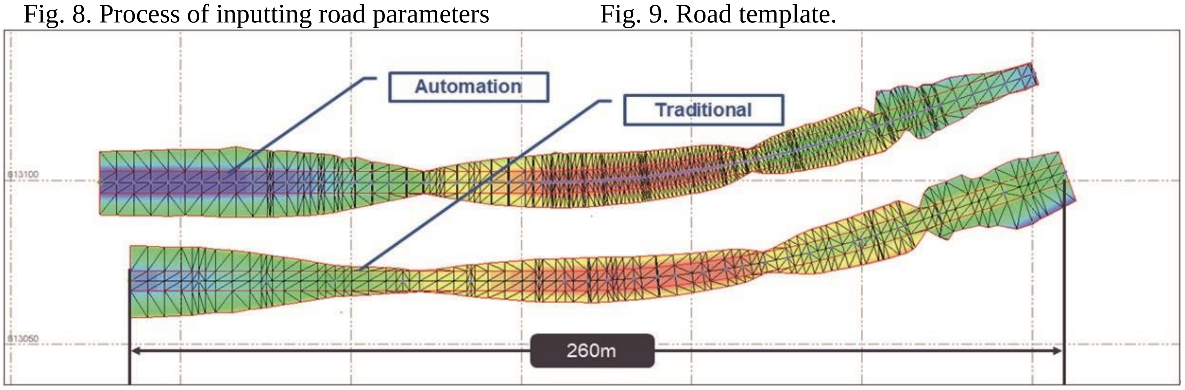

Fig. 10. Completed 3D design.

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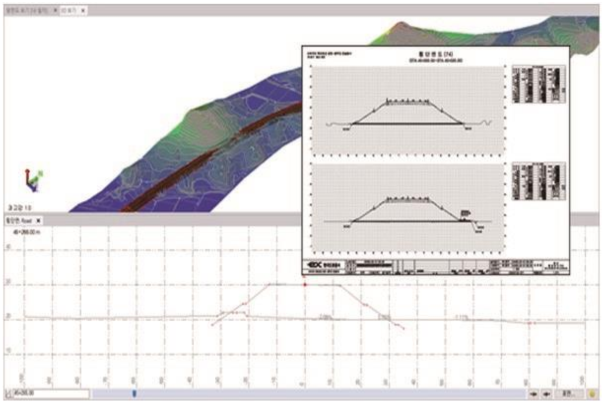


Fig. 11. Design check.

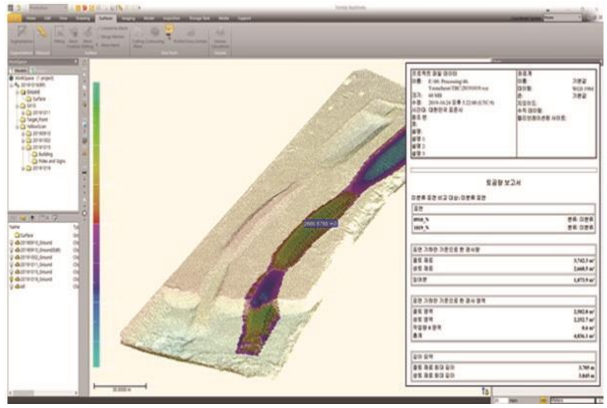


Fig. 12. Calculation of the amount of earthwork.

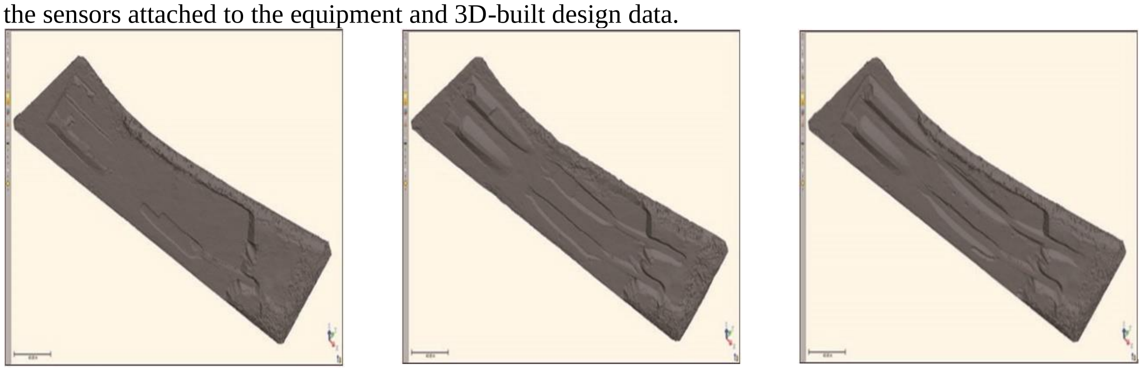
various sensors were installed on the construction equipment, such as hydraulic sensors and GNSS, and modems for communication were also installed. Figure 15 shows the construction equipment and sensors.

Fig. 13. Work screen for automated construction.

In the traditional road construction method, it is necessary to continuously perform GNSS surveys during the work and compare and correct the design values. However, automated construction has the advantage of knowing the values and the condition of the site in real-time using the sensors installed on the equipment. Figure 13 shows the work screen for automated construction.

The traditional and automated construction methods were applied at the target site, and the data obtained using static LiDAR and UAV LiDAR were acquired at stages corresponding to 20, 80, and 100% of the construction being completed. Figure 14 shows geospatial information of the study area for each stage of construction. Visualizing the process in a real-time construction site was also tested. This method uses augmented reality (AR), a GNSS receiver, and a smartphone can be used to manage construction in the field (Fig. 15). This method has the advantage of being able to check the process in a real-time construction site by comparing it with the design.

The LiDAR data acquired during construction work can be used for monitoring and checking construction. In addition, if a network is established, it will significantly help manage construction in real-time by using the data from the sensors attached to the equipment and 3D-built design data.



(a) (b) (c)

Fig. 14. Geospatial information of the study area for each stage of construction: (a) 20, (b) 80, and (c) 100%.

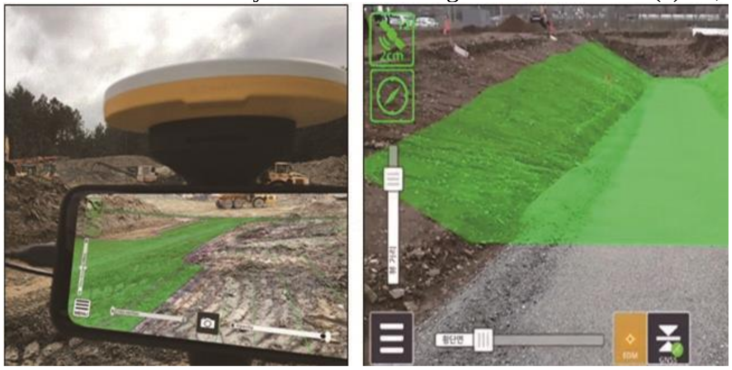


Fig. 15. Construction management using AR.

Conclusion

The present study examined the application of 3D geospatial information technology in road construction in Edo State, Nigeria. The finding indicates that GNSS, static LiDAR, and UAV LiDAR were effective in building 3D geospatial information of the study area. The result agrees with other studies that have established efficiency in geophysical survey equipment (Gaballah & Alharbi, 2022; Grigoriev et al., 2021). The accuracy of data constructed through static LiDAR and UAV LiDAR was established considering the small size of the study area. The accuracy of LiDAR will need to be verified through additional research. A 3D design reflecting the actual terrain was created, and various sensors were installed on the construction equipment to conduct experiments on construction automation. Construction automation has the advantage of knowing the design values and the condition of the site in real-time using the sensors installed on the equipment. The productivity of construction automation was evaluated by comparing the results of traditional and automated construction processes. A construction approach incorporating geospatial data and augmented reality produces on-site visualization, which aids in project management. Construction automation will enhance future productivity for roads and other building sites, such as tunnels, by utilizing 3D geospatial information technology.

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