Proceedings of the 10th International Conference on Civil Structural and Transportation Engineering (ICCSTE 2025)
July, 2025 | Imperial College London Conference Center, London, United Kingdom
Paper No. 208
DOI: 10.11159/iccste25.208

Improving Earthwork Planning with the implementation of BIM and UAV: Case study applied in the surroundings of the Chancay mega-port - Peru - 2024

Leonardo Apaclla[1], Nicolás Pardo[2], Goyo Alvarez[3], Alvaro Jaen[4], Sandra Rodríguez[5]
[1]U202017268@upc.edu.pe School of Civil Engineering, Peruvian University of Applied Sciences
Lima, Peru
[2]U202115280@upc.edu.pe School of Civil Engineering, Peruvian University of Applied Sciences
Lima, Peru
[3]goyo.alvarez@upc.edu.pe School of Civil Engineering, Peruvian University of Applied Sciences, Lima, Peru
[4]alvaro.jaen@doc.uto.edu.bo School of Civil Engineering, Technical University of Oruro, Oruro, Bolivia
[5]sandra.rodriguez@upc.edu.pe School of Civil Engineering, Peruvian University of Applied Sciences, Lima, Peru

Abstract **-** The lack of necessary information and the lack of accuracy presented in this, causes direct damage to the planning process of a construction project, due to problems such as cost overruns or delays, caused by the incorrect distribution of resources allocated for the completion of activities. In earthmoving work, the deficient collection and processing of information is an index of the bad procedure that a company has and causes the activities to present additional costs due to rework, dissatisfaction on the part of the client or delays in the delivery within the predetermined deadlines. That is why this article proposes the implementation of unmanned aerial vehicles (UAV), in conjunction with BIM software, as tools for the collection, processing and sharing of information. This will be more complete and will allow a programming based on qualitative and quantitative data in a precise, fast and understandable way for those interested in the execution process of a construction project, which, being located in an area of high demand due to its proximity to the mega port of Chancay, will allow the earthwork execution procedure to be carried out in an efficient and fast way, avoiding harming the construction company.

Keywords**:** UAV, BIM, photogrammetry, earthwork, planning.

1. Introduction

The planning process is the first step in a construction project, since it defines the order of the activities to be carried out. However, this can be affected due to the lack of information collected and the lack of accuracy, because a schedule is made where quantitative and qualitative data are missing; in addition, the accuracy of the same must also be as accurate as possible, thus ensuring that resources such as materials, equipment and labour are distributed efficiently and do not generate risks of cost overruns and/or delays in the delivery of the project. To improve the collection, processing and production of new data in earthwork, multiple authors support the use of UAV (Unmanned Aerial Vehicle) as a potential tool for such work, due to its ability to cover a large area for the collection of information (georeferenced points), with the most updated equipment being able to obtain an error of only a few centimeters. In addition, by integrating a collaborative platform that allows multiple workers to intervene in the development of other tools that facilitate planning, such as BIM software, important for the processing and sharing of data obtained in the field, they can provide engineers with accurate, fast and easily understandable information. This article covers the development of the data for its collection, processing and subsequent analysis of the results presented and the role of each one in the search for an improvement in the planning of activities. The main purpose of the academic article is the provision of information obtained quickly and accurately, so that it can be applied by engineers in the allocation of resources needed to complete each stage of the project, without problems related to cost, time and constraints.

2. State of the art

Regarding the inclusion of BIM methodology, the article mentions about the objective in a tunnel project from a good coordination and performed on the basis of concise and complete information. Thus, the main problem is explained in [3], "the variability of this data could be lost in some projects due to the complexity and variation of the parameters". The process that is carried out to reach this end begins with the search for the necessary information present in the field, the field data is collected, the obtained data is uploaded to a canva for the exchange of these, so that a correct collaborative process can be carried out. Finally, the data can be modeled in a 3D view in software such as Revit, Rhino, among others.

According to the article [2], earthwork represents a high percentage of the total construction budget, due to the purchase of machinery and equipment for cutting and filling. In view of this, having the information available during the planning period would mean being able to better allocate resources for the machinery and equipment needed for earthwork. This is supported by [4], the article mentions that the earthmoving activity presents a great demand on the cost issue, largely due to the large equipment that respect the works and the necessary precision they require. In many occasions ending up in rework, which is mentioned to be caused by design flaws and a non-optimized or inefficient earthwork.

Delving into the issue of costs, the subsequent article [5], exposes as the main problem to be solved the cost overruns caused by the time consumption in the earthwork stakeout mainly produced by a faulty design and a poorly optimized planning. Therefore, they present the use of a design and planning model from a point cloud obtained by UAV and based on BIM methodology. Ground control points (GCP) were installed, with the intention of improving the accuracy of the point to cloud, obtaining points from the GCP placed, controlling the coordinates and characteristics of the drones, the point cloud was obtained by photogrammetry technique. In order to consider the maximum precision in the location of the points, factors such as obstacles, altitude for taking photos, flight time, among others, were considered. The data obtained help in the earthwork item, since they offer the calculation of volumes for the restrictions of the subsequent items to be performed.

Finally, the difficulty in the calculation of earth volumes in irregular curves located in different terrains causes waste of money and prevents an economically sustainable construction. For this reason, the article proposes the use of UAVs (unmanned aerial vehicles) to perform the calculation of soil volumes. The calculation is made from photogrammetry, a technique that seeks accuracy, position, shape and dimensions; applied in the calculation of earthworks, it creates a point cloud that contains the necessary information to be exported to a software (Revit), so that it can produce a model capable of quantifying the volume that, during the execution of the work, it will be necessary to cut and fill the material. The result of this study showed that for the calculation of the earthwork volume using UAV, in the case of earth cut sections, a shorter chain interval will allow obtaining the earthwork volume based on the digital surface model (DSM). In addition, in the case of embankment sections, the chain-based embankment volume was generally smaller than the DSM-based embankment volume. Theoretically, DSMs contain more meaningful information than 2D-based cross sections. Therefore, the DSM-based embankment volume calculation method is expected to have greater applicability in the field, as it yields a result closer to the actual value [6].

3. Current Situation

3.1. Chancay Megaport - Lima, Peru

At the time of writing, the Chancay mega-port is in the final stages of construction. It was proposed to provide greater accessibility to exports and imports by sea, thus improving the Peruvian economy. Other objectives of the mega-port are to reduce administrative, economic and capacity problems.

3.2. Why was Chancay chosen as the study area?

The decision was made to choose Chancay as the place to carry out our research because of the boom that the construction sector would see in this area due, for the most part, to the inauguration of the mega-port. This fact means a great attraction for investors, who are looking for the construction of projects near the mega-project. That is why we have seen in this fact, an opportunity to apply our research in a way that generates an impact on the projects to be carried out in the future.

3.3. Expectations for the implementation of proposed tools

From the implementation of unmanned aerial vehicles, in collaboration with BIM software, with which a collaborative environment between stakeholders is sought; it is expected that the collection of information obtained in the same field, quickly and accurately so that its processing is in the same way. With this, it is expected that the point cloud, plans, models and volume calculations will serve as applicable information to improve the planning of earthwork activities.

Fig. 1: Chancay Megaport

4. Used Tools

GNSS CHCNAV I93 was used, which has one thousand four hundred and eight channels that track major constellations such as GPS, GLONASS, among others; it has real-time precision, has two cameras with global shutter of 2 MP and 5 MP.

Table 1: Main characteristics of the equipment used GNSS CHCNAV I93

Specification	Description
GNSS Channels	GNSS Channels 1408 channels tracking all major constellations GPS (L1, L2, L5), BeiDou (B1, B2, B3), GLONASS (F1, F2), and Galileo (E1, E5A, E5B).
Real-time precision	Horizontal: 8 mm + 1 ppm RMS Vertical: 15 mm + 1 ppm RMS
RTK initialization time	Less than 10 seconds
Reliability of initialization	Greater than 99.9%
Auto-IMU	200 Hz IMU with automatic initialization. Up to 30° baton tilt compensation.
Cameras	Two 2MP and 5MP global shutter cameras, OmniPlex®-GS technology. Photogrammetric video capture with up to 85% overlap.
3D visual stakeout	3D navigation and stakeout with immersive visualization. Increased efficiency up to 50% for less experienced operators.
Protection	IP67, shock, dust and water resistant. Withstands drops of up to 2 meters.
Connectivity	Wi-Fi IEEE 802.11a/b/g/n/ac, Bluetooth 5.0 and 4.2, NFC, integrated 4G modem (TDD-LTE, FDD-LTE, WCDMA, EDGE, GPRS, GSM), integrated UHF.
Internal storage	32 GB internal memory, expansion up to 128 GB.

Operating temperature	From -40°C to +65°C

The D-RTK 2 mobile station is also used, it has GNSS channels that receive GPS, BeiDou, and other signals; it has RTK accuracy and can operate at temperatures from -20°c to 55°C.

Table 2: Main characteristics of the equipment used D-RTK 2

Specification	Description
GNSS Channels	Simultaneously receives GPS (L1, L2, L5), BeiDou (B1, B2, B3), GLONASS (F1, F2), and Galileo (E1, E5A, E5B) signals.
Real-time precision (RTK)	Horizontal: 1 cm + 1 ppm RMS Vertical: 2 cm + 1 ppm RMS
Update rate	1 Hz, 2 Hz, 5 Hz, 10 Hz, y 20 Hz
IMU	High-precision 6-axis accelerometer, slope measurement and electronic spirit level.
Operating temperature	From -20°C to 55°C (-4°F to 140°F)
Classification	IP65, water and dust resistant
Storage capacity	16 GB of internal memory

Regarding the drone used, this corresponds to the Phantom 4-RTK DJI, which weighs 1391g, has a maximum speed of 50 kph in P mode and 58 kph in A mode, has a maximum flight time of about thirty minutes and has a maximum transmission distance of about 7 km (FCC) and 5 km (CE).

Table 3: Main characteristics of the equipment used Phantom 4-RTK DJI

Specification	Description
Update rate	Approximately 30 seconds
Maximum flight time	Approx. 30 minutes
Real Time Kinematics (RTK) accuracy	Horizontal: 1 cm + 1 ppm RMS Vertical: 1.5 cm + 1 ppm RMS
Camera	1-inch CMOS sensor, 20 MP; Mechanical shutter: 8-1/2000 s
System	GNSS GPS, GLONASS, BeiDou, Galileo
Maximum transmission distance	7 km (FCC), 5 km (CE)
Gimbal	3-axis stabilization (tilt, roll, yaw)

About the software used, the first was Agisoft Metashape Professional, which is used to generate the point cloud, this software is compatible with the drones DJI Mavic 3, Enterprise, SJI Matrice 300 RTK, SenseFly eBee X, Parrot

Anafi USA, WingtraOne, Quantum Systems Trinity F90 and DJI Phantom 4 RTK. Autodesk Civil 3D software was also used to process information provided by Agisoft and obtain results that will be later visualized.

The Building Information Modeling - BIM methodology aims to apply a collaborative system between the different professionals and workers involved in the project, which allows the collection, compilation and storage of information, in order to reduce conflicts during the project execution stage. Likewise, in [1], they mention that “when properly applied, BIM facilitates a more integrated design and construction process that results in higher quality buildings at lower cost and with a reduced project duration”.

5. Procedure

The procedure for the collection of information is divided into two parts, one corresponds to the collection of data in person, which corresponds to the placement of georeferenced points, use of the drone and collection of the first data from the field; while the second part corresponds to the processing of the data previously obtained, in which the aforementioned software is used and the results are obtained that will be implemented for planning.

5.1. Physical procedure: Data collection with drone

Once located on the ground, we proceeded with the verification of the optimal weather conditions for the flight of the drone, among the main climatic requirements are a clear sky, wind gusts and favorable temperature. It should also be noted that the drone was piloted by a professional, who is certified by the pertinent entity, and the vehicle to be piloted also has its own certificate. The steps followed in the field for data collection are explained below.

The first step was to place and obtain the coordinates of georeferenced points (necessary to increase accuracy during the processing of the point cloud in the software).

After that, the route to be followed by the drone is planned, which must cover both the interior and the surroundings of the terrain, so that the points can be correctly located.

Once the drone flight was completed, the photographs were captured in its storage and the images were processed.

5.2. Data Processing: Agisoft Metashape Professional Software

Once the drone images were obtained, we processed them in Agisoft Metashape Professional to obtain the point cloud, obtaining a total of 52,082,850 points.

After this we make a 3D Modeling and a Tessellated Model, with which we will be able to walk and observe all the terrain where the drone has flown over.

Finally, a Digital Elevation Model - DEM was made which shows the different heights according to the different levels observed in the terrain.

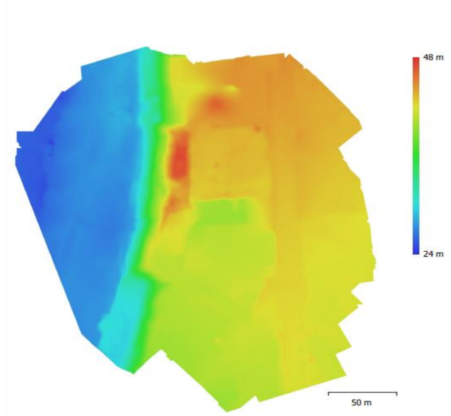

Fig. 2: Digital elevation model (DEM)

5.3 Data processing: Civil 3D software

After processing the point cloud, it must be in rcp. format, that is why before importing it into Civil3D, you must make use of the Recap Pro software, used only to change the format so that it can be transferred to Civil 3D.

In the correct format, the point cloud is imported into the software, and we start by creating a surface from it.

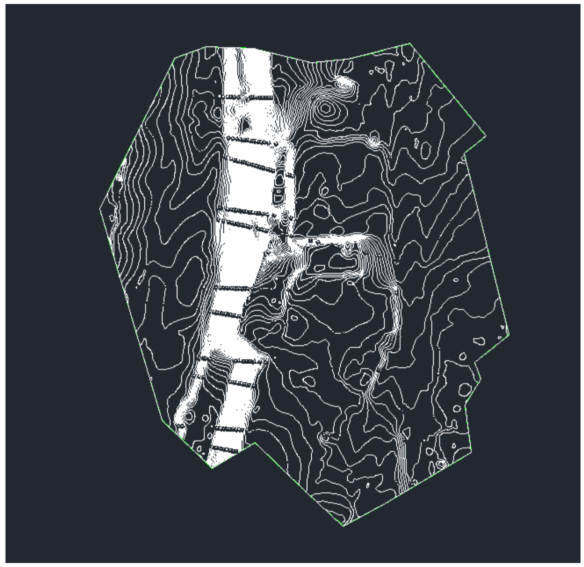

Fig. 3: Surface obtained in Civil3D

Once the surface is obtained, we proceed to perform the calculation of cut and fill, in order to know the respective volumes.

Finally, from the surface created, a 3D model will be made, which will be used for later planning in terms of sectorization and location of crews to perform activities on the ground.

6. Results

6.1 High precision in processing and obtaining information

The use of georeferenced points allows greater accuracy in the collection of information, therefore the models, data and calculations obtained present accurate information that endorse their use in the planning of earthwork activity. In the following table we can observe the errors obtained in the Agisoft Metashape Professional software, with respect to the “X”, “Y” and “Z” axes.

Table 4: Errors with respect to X, Y and Z.

Error in X (cm)	Error in Y (cm)	Error in Z (cm)	Error in XY (cm)	Combined error (cm)
0.8986	1.0295	2.1070	1.3665	2.5113

6.2 Recording of information

From the processing of the information with the help of data through software such as Agisoft Metashape and Civil3D, it is possible to obtain elements that allow a better understanding. Among these are:

Digital Elevation Model (DEM): This is used three-dimensional that allows observing the variation of heights within the analyzed terrain.

Point cloud: This document contains the set of georeferenced clouds, obtained from drone image capture. From this information it is possible to process specific parts of the territory to obtain surfaces, plans, volumetry, etc, etc.

2D and 3D models: Both models allow a better perception of the characteristics of the territory. They also allow to divide the areas of intervention by the crews to work, influencing the planning.

6.3 Calculation of earthwork volume

This calculation turns out to be more accurate compared to the traditional method, because this calculation was obtained from a surface based on precise points.

Table 5: Total cut and fill volume

	VOLUME (m3)
Cut	23 969.75
Fill	15 908.04

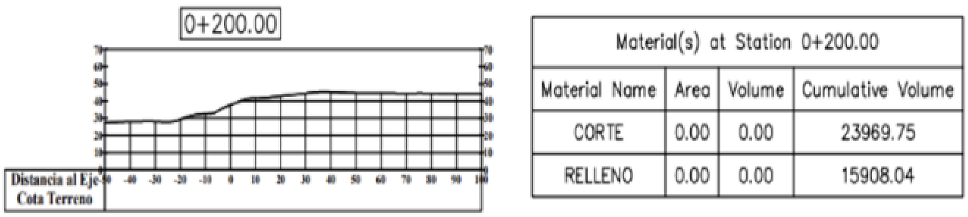

Fig. 4: Total cut and fill volume developed in Civil 3D.

6.4 Fast procedure and results acquisition

Compared to traditional methods, data acquisition is completely dependent on the size of the terrain; however, it is still fast, taking approximately 30 minutes to collect images for a 7200 square meter terrain. Also, the ease with which these photographs can be processed by software allows models, plans, etc., to be obtained more quickly and easily understood by stakeholders in the progress of earthworks.

7. Analysis of results

With the results obtained, the respective analysis has been carried out, where improvements in planning would be seen by applying the above mentioned.

7.1 Time

By applying the topographic survey with drones - UAV provides the construction project with “fast” and “accurate” information, since this proposed method allows covering large areas, so the size of the terrain would not be a problem, in addition to the fact that from the images captured by the drone, the point cloud is obtained automatically by means of “Agisoft”.

7.2 Sectorization

Having the surface from the point cloud and making a 3D model from the surface, the engineer is able to distribute the terrain with their respective crews, allowing them to distribute strategically to perform a continuous workflow. In addition to the fact that the understanding of the operators in charge improves, since being able to visualize a 3D model, their understanding when executing it in the field would be clearer.

7.3 Planning

The factors seen previously have a direct influence on the planning of the earthwork activity, since, through the collection, examination and transfer of information shared among those involved in the project. Likewise, with the information acquired it is possible to carry out work trains, analysis of restrictions, look ahead and in this way contribute to the optimal planning of the earthmoving activity.

8. Conclusions

The article proposes the implementation of unmanned aerial vehicles, in collaboration with collaborative software (BIM) in order to offer an improvement in the planning of earthwork activities. The contributions of the article are the following mentioned:

Obtaining accurate and fast information with the use of drones (UAV), which allow obtaining georeferenced points in areas of greater extension, reducing time and costs compared to the traditional method.

Obtaining digitized information that can be shared among collaborators, which directly influences the decisions taken during the planning process.

The application of photogrammetry and the collaborative work offered by BIM presents a proposal for the future, in which information can be digitized and shared among project stakeholders. However, this application still presents some limitations, such as the limitations to perform the work on days with unfavorable weather and its application on land that includes bodies of water in its area (due to its inability to calculate points in water); therefore, this article serves as a basis for future research that can complement the above mentioned, some of them include the inclusion of virtual reality technology, so that progress can be visually recorded according to the schedule and weekly objectives to be achieved sequentially.

9. Acknowledgments

To the Research Department of the Peruvian University of Applied Sciences for its support in carrying out this research project through the UPC-EXPOST-2025-1 incentive.

10. References

[1] Eastman, C., Teicholz, P., Sacks, R. & Lee, G. BIM Handbook. Editorial Wiley. https://tinyurl.com/29zkwmn8, 2008.
[2] Gwak, H., Seo, J., Lee, D. Optimal cut - fill pairing and sequencing method in earthwork operation. Automation in Construction. 87, 60 - 73. https://doi.org/10.1016/j.autcon.2017.12.010, 2017.12.010, 2018.
[3] Hedayatzadeh, M., Rostami, J., Sarhosis, V., Nematollahi, M., Hajian Tilaki, N., Shafiepour, A. Use of GIS and BIM for the integration of tunnel design and construction process in conventional tunneling. Underground Space. 16, 261-278. https://doi.org/10.1016/j.undsp.2023.10.009. 10.009, 2024.
[4] Kim, J., Lee, S, Seo, J., Lee, D., Choi, H. The Integration of Earthwork Design Review and Planning Using UAV-Based Point Cloud and BIM. Applied Sciences. 11(8). https://doi.org/10.3390/app11083435, 2021.
[5] Kim, Y., Shin, S., Lee, H., Park, E. Field Applicability of Earthwork Volume Calculations Using Unmanned Aerial Vehicles. Sustainability. 14(15), 1-24. https://doi.org/10.3390/su14159331, 2022.
[6] Lee, K., Hee, W. Earthwork Volume Calculation, 3D Model Generation, and Comparative Evaluation Using Vertical and High-Oblique Images Acquired by Unmanned Aerial Vehicles. Aerospace. 9(10), 606-626. https://doi.org/10.3390/aerospace9100606, 2022.