APPLICATION OF DIFFERENT GEODETIC METHODS IN CLAY VOLUME MEASUREMENT FOR BRICK PRODUCTION

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ABSTRACT

The purpose of this research is to present the outcomes of volume calculations using three distinct surveying technologies: total station, GNSS, and UAV. A comprehensive examination of each of these methods is conducted and subsequently applied to the same project, which involves measuring the volume of clay for a factory in Novi Bečej. The time required for surveying, data processing, and the resulting volume calculations are scrutinized to determine the most suitable approach. Each method offers its own set of advantages and limitations, and the decision on which method to employ hinges on the specific project requirements and the desired level of precision. The disparities in the results underscore the significance of selecting the most fitting method for a given application while taking into account potential uncertainties and errors.

KEYWORDS:

clay, total station, UAV, GNSS, surveying, volume calculation

1 INTRODUCTION

In modern geodetic practice, field surveying is a key component in the collection and analysis of spatial data. Effective field surveying methods enable accurate collection of terrain information, shape and dimensions, which is essential in many industrial sectors.

The rapid development of technology and the increasing demands for efficient methods of field surveying in geodetic and construction projects have given rise to new methods that ensure precision, accuracy and efficiency in the collection of spatial data [1]. One of the most important sectors that relies on accurate and detailed information about the field is the roof tile production industry, and one of the leading factories in that domain in Republic of Serbia is "NEXE" in Novi Bečej.

The aim of this paper is to analyse and compare field surveying methods, with a special focus on total station, GNSS and unmanned aerial vehicles (UAV), in the context of surveying the clay used for the production of roof tiles in the "NEXE" factory.

2 BACKGROUND AND METHODS

In practice, there is often a need to calculate the volumes of excavated, transported, installed, deposited and disposed material. Volumes can refer to solid or loose rock and other mass. Sometimes it is necessary to determine the volume of empty spaces in which certain material will be placed. Depending on: shape of figure, required accuracy, speed and available equipment, volumes can be determined by non-geodetic or geodetic methods.

2.1 NON-GEODETIC METHODS

As for methods that are not purely geodetic, volumes can be determined based on [2]:

- volumes of truck or wagon crates (applied for calculating volumes of transported material in crates),
- material mass and density (applied for calculating volumes of material transported by trucks and barges),
- material flow on conveyor belts (applied for calculating volumes of material transported by conveyor belts)

2.2 GEODETIC METHODS

The choice of an adequate method of calculating the volume depends on the shape and amount of excavation and embankment between the projected levelling surface and the surface of the natural terrain, the relief of the land, the required accuracy and the equipment and data at our disposal. The volume of earthworks is calculated up to 0,1 m³. In the following, some of the geodetic methods of calculating volumes will be described [3].

2.2.1 Calculation of material volumes based on horizontal sections

Calculating volumes based on horizontal sections is rarely used today. The surfaces of the horizontal sections represent the areas covered by the isolines. This method can be successfully applied to calculate the volume of deposited material or water accumulations. For a body whose volume is calculated, it is necessary to draw isolines based on a series of recorded points, and then calculate the areas covered by those isolines [2].

2.2.2 Calculation of material volumes based on vertical sections

This method of calculation is most often used in practice, and the reason is the simplicity of its application. It is mainly used when calculating the volume of earthworks for the construction of roads, railways, canals and surface exploitation of mineral raw materials. The method is based on geodetic surveying of the terrain before and after construction and other mechanization works, according to profiles in defined places. Then, based on two geodetic surveys, terrain lines are drawn between which the areas of the figure are calculated.

The distance between the profiles is a key factor that affects the accuracy of the volume calculation. In addition to the spacing of the profiles, the accuracy of the volume calculation is significantly affected by the selected position of the profile. By reducing the distance between the profiles and increasing the number of recorded points in the profiles, the precision of the calculated volumes can be increased [2].

2.2.3 Calculation of volume based on a network of triangles

To calculate the volume based on triangular prisms, the bases of the prisms can be regular or irregular triangles. Differences in height between two states on the terrain at vertices of triangles are determined through direct geodetic measurements in the field or are interpolated based on recorded points [2].

2.3 GIS TOOLS FOR VOLUME DETERMINATION

The expansion of information technology has led to the development of numerous software packages for 3D design, modelling, and spatial database integration. The use of these software packages is prevalent in geodesy. Some of the most well-known software packages include AutoCAD Civil 3D, ArcGIS, TopoCad, and others [4,5,6]. Their application allows the straightforward determination of volumes.

AutoCAD Civil 3D is a software package that possesses all the necessary tools for designing and conducting complex analyses, primarily in the field of civil engineering. It is intended to specific engineering requirements, combining CAD functionality, creation and analysis of Digital Terrain Models (DTM) [7], work with parcels, and the formation of linear object alignments. For the purpose of calculating volumes, AutoCAD Civil 3D software necessitates two Digital Terrain Models (DTMs): one representing the base state and the other the current state. The process involves overlapping these two DTMs to readily visualize changes in the terrain (see Figure 1). The accuracy of volume calculations relies on the precision with which the base and current state DTMs are generated [3]. AutoCAD Civil 3D includes a Survey module primarily designed for surveying professionals. This module encompasses a suite of tools for importing measurement data, performing various calculations, and automating the assignment of relevant symbols through the use of codes. AutoCAD Civil 3D facilitates the creation of DTMs in grid and Triangular Irregular Network (TIN) formats. The TIN algorithm is rooted in Delaunay triangulation, ensuring unambiguous results [8]. The terrain surface is represented by triangular facets, with each vertex corresponding to points collected during the geodetic survey of the terrain. When creating a digital DTM, structural lines, contours, and objects can be employed as long as their spatial positions are defined. During DTM creation, one must select the model type, the layer for display, and the model's display style. In configuring the display style, you can specify which elements to show (such as points, contours, triangles, etc.) and define contour intervals.

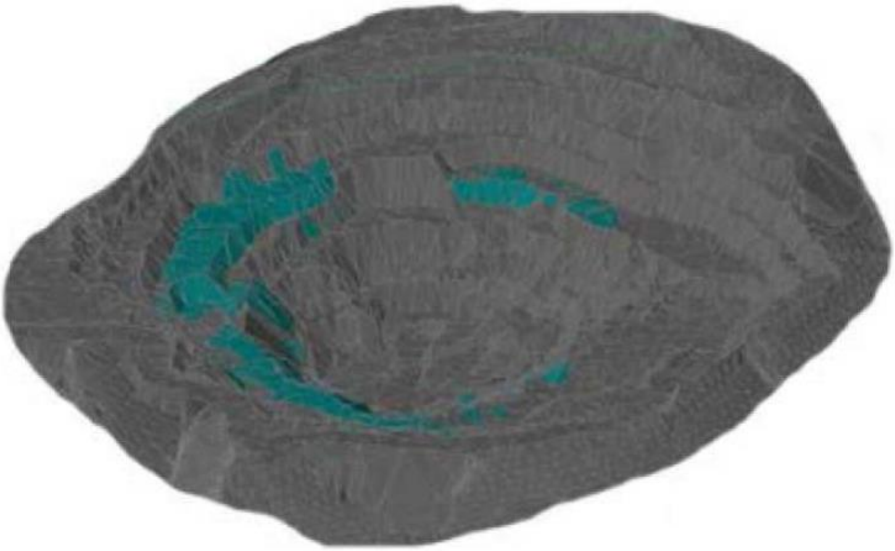

Figure 1: Overlapping the base model (green color) and the current state (gray color) [9]

3 RESULTS

When it is necessary to calculate the volume of clay in a specific area, there are different measurement methods that can be applied. Three methods that will be compared in this study are measuring clay using the total station RUIDE RIS, clay measurement with the GNSS device RUIDE R6, and using an UAV. The analysis was performed by measuring clay used for tile production at the NEXE factory in Novi Bečej. The survey area is shown in Figure 2 [10].

The first method, measuring clay using the total station RUIDE RIS, provides precise data collection about the terrain's topography. Using this method, points are surveyed with the total station, using markers for additional survey methods. This method provides detailed information about the terrain but requires more time in the field and data processing in the office [11].

Figure 2: Area of interest

The second method to be compared is measuring clay with the GNSS device RUIDE R6. This method utilizes GNSS technology to precisely locate points on the terrain. GNSS devices provide fast and highly accurate surveys and can be efficient for data collection over larger areas.

Figure 3: Devices used for surveying the area of interest

The third method that will be used is surveying using UAV. This technique uses drones as a platform to capture aerial terrain data. Drones equipped with cameras take a series of photographs of the terrain from different angles. These data are then processed using specialized software applications to generate a three-dimensional terrain model.

All three used devices are presented in the Figure below with their specifications in Table 1:

Table 1: Main characteristics of used devices

Type	Manufacturer	Model	Accuracy
Total station	Ruide	RIS	2"/ (2 + 2*D mm)
GNSS	Ruide	R6	H: 2,5 + 0,5*D mm/V: 5 + 0,5*D mm
UAV	Dji Mavic	2 Pro	flight H: 1,5 m/V: 0,5 m

Comparing these measurement methods for calculating clay volume aims to identify the advantages and disadvantages of each method. Factors to consider include the accuracy of collected data, the time required for surveying and processing, as well as the complexity of each method. The goal is to discover the most suitable method for a specific clay volume measurement project.

3.1 SURVEYING THE AREA OF INTEREST WITH A TOTAL STATION

Measuring clay using the total station RUIDE RIS allows precise data collection about the terrain's topography. With the help of this station, it is possible to survey points on the terrain with high accuracy and precision. Additionally, markers are used to capture different perspectives of the terrain. A total of 110 points were surveyed using three stations. These points represent detailed information about the clay's topography in a specific area. The number of points may vary depending on the project requirements, but in this case, 110 points were sufficient for obtaining an accurate digital elevation model (Figure 4).

The time required for surveying points in the field was 2,5 h. This included setting up the total station at the appropriate points, surveying points from each of the stations and recording relevant data. This process demands expertise and attention to ensure the accuracy of the collected data. After completing the field survey, the data were transferred to the office for further processing. Data processing took 30 min, which involved inputting and analysing the surveyed points, generating DTM and calculating the clay volume.

Utilizing the polar method for surveying the points yielded a clay volume of 10.334,32 m³ [2].

3.2 SURVEYING THE AREA OF INTEREST WITH A GNSS

Using the GNSS device RUIDE R6, a total of 160 points were collected in the field. These points represent detailed information about the clay's topography in a specific area. GNSS devices allow precise point location based on satellite signals, resulting in high data accuracy [12]. After completing the field survey, the collected data were transferred to the office for further processing. This phase involves transferring data from the GNSS device to a computer, data analysis and organization, generating a DTM (Figure 5), and calculating the resulting clay volume. Through the application of GNSS technology, the survey results with the GNSS device RUIDE R6 revealed a clay volume of 10.425,14 m³.

Surveying clay with the GNSS device RUIDE R6 is an efficient and precise method for collecting terrain data. With 160 surveyed points, 1,5 h spent in the field, and 30 min of data processing in the office, rapid and reliable terrain analysis can be achieved [10].

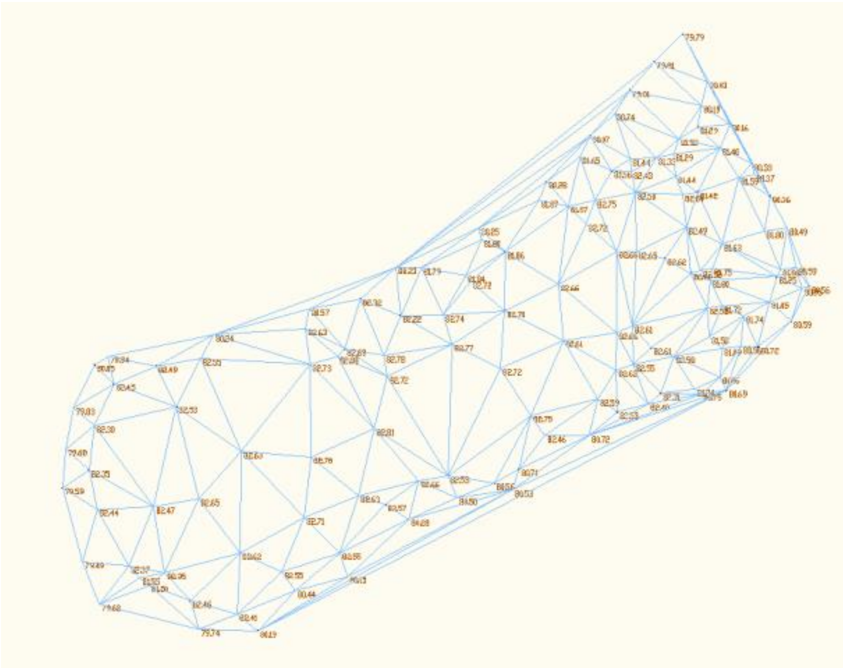

Figure 4: The triangle network surveyed with total station [10]

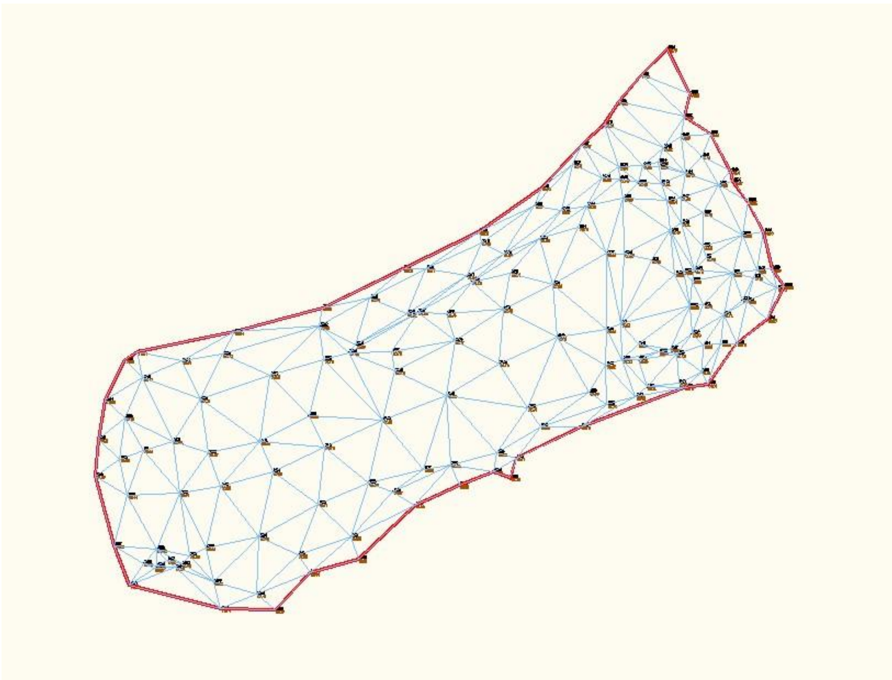

Figure 5: The triangle network surveyed with GNSS [10]

3.3 SURVEYING THE AREA OF INTEREST WITH A UAV

Using the DJI Mavic 2 Pro drone, the survey was conducted using the Pix4D application, which allows flight planning and data collection. The flight plan had a duration of 6 min and 12 s, with the UAV flying at an altitude of 60 m. This flight plan enabled the terrain to be captured from an appropriate height to achieve the desired precision and resolution.

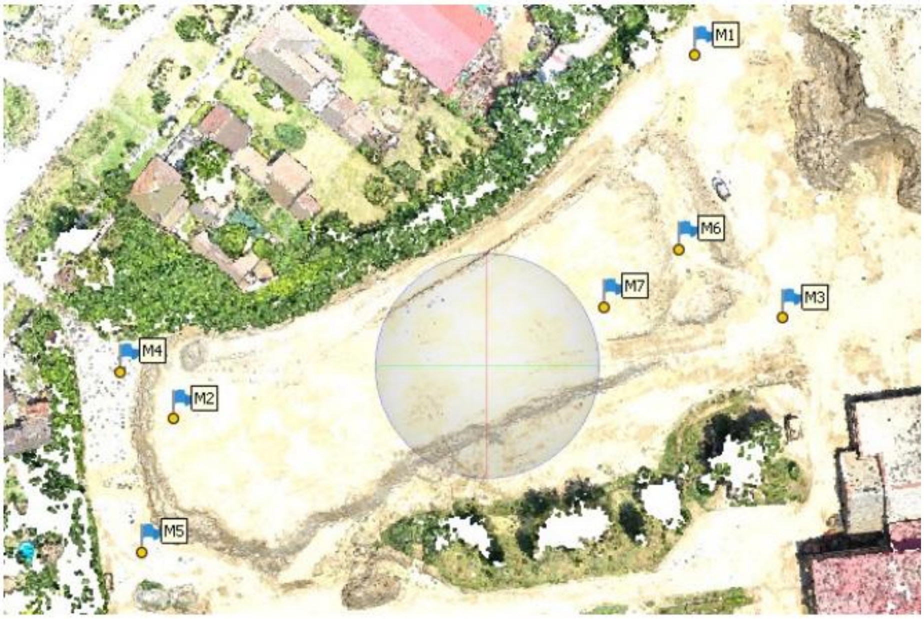

Figure 6: Distribution of markers [10]

The image overlap parameters were set to 60% overlap forward and 70% overlap sideways. These parameters ensure adequate image overlap and enable precise generation of a three-dimensional terrain model. After the survey, the data were transferred to the Agisoft Photoscan application for processing [13]. By processing the data in this software, approximately 14.000.000 points were obtained. These points represent precise terrain information used for further analysis and the generation of three-dimensional models.

The processing time in the Agisoft Photoscan application is approximately 5 h. It is important to note that this time can vary significantly depending on the computer's specifications used for data processing.

Using Civil 3D software, the volume between two three-dimensional terrain models was calculated. The result of this calculation showed a volume of 10.491,59 m³.

Figure 7: Orthophoto Created in Agisoft Photoscan [10]

4 DISCUSSION

The analysis of the results obtained from different methods of measuring clay volume - total station, GNSS, and UAV surveying - provides insight into the differences in results and the accuracy of each method. According to the results obtained from total station surveying, the clay volume is 10.334,32 m³. On the other hand, results from GNSS surveying show a volume of 10.425,14 m³, while UAV surveying with photogrammetry resulted in a volume of 10.491,59 m³.

Based on the analysis of these results, it is observed that there is a slight difference in the volume obtained between the measurement methods. UAV surveying provides the highest clay volume, while the results from total station surveying and GNSS surveying are slightly smaller (Figure 8).

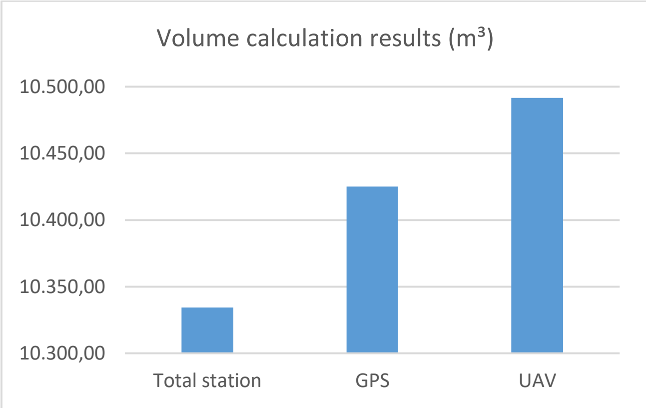

Figure 8: Volume calculation results

The differences in results can be attributed to several factors. First, each method has its characteristics and accuracy in data collection. UAV surveying offers the ability to collect a larger number of points with high precision from various angles. On the other hand, total station surveying and GNSS surveying may have certain limitations in the precision of collected data.

It's also important to consider other factors such as time constraints while choosing the optimal method. Below are presented Figures 9 and 10 with time limitations for all three used methods.

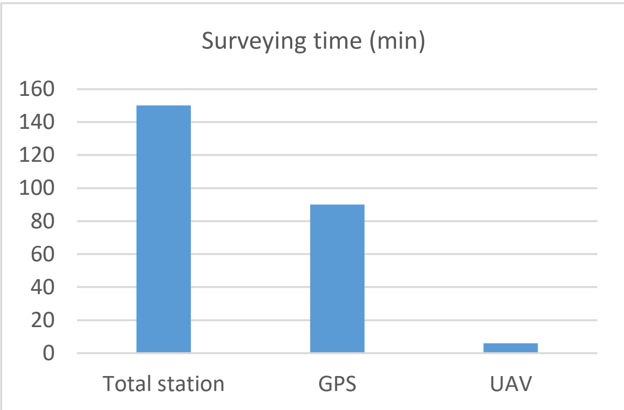

Figure 9: Surveying time comparison between all three used methods

In the Figure 11 are presented together required time periods for data surveying on the field and data processing in the office. The idea was to show comparative analyses of all three methods, from those aspects. It turns out that UAV required the least time in the field (less than 7 min), but the much more time in the office, comparing to other methods. In sum, it seems that UAV took most time. But, it should be taken into account that the work in the office (post-processing of data) has a lot of automatic tools. That means, that we just run some processes; not during all 5 h operator is in the front of the PC and doing something, because some period he is just waiting background processes. In the other hand, total station and GNSS required time periods are similar, but GNSS has slightly advantage. Working with GNSS on the field is easier and faster than working with total station, while processing time were the same.

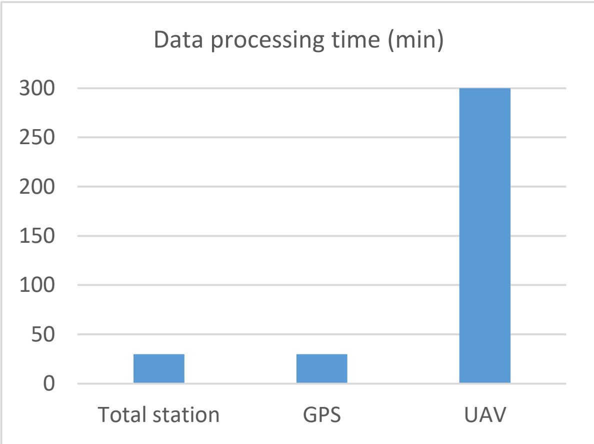

Figure 10: Data processing time comparison between all three used methods

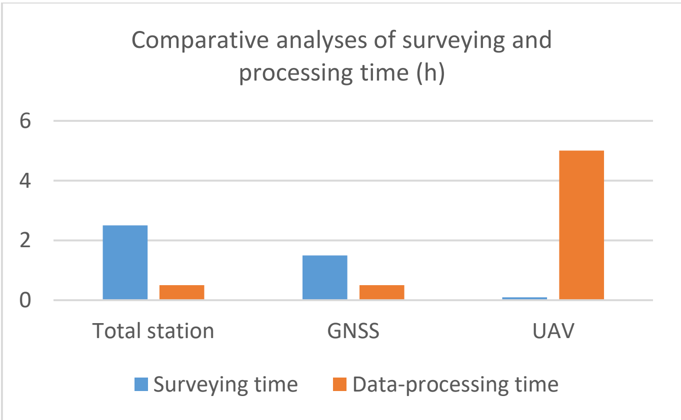

Figure 11: Surveying and data processing time comparison between all used methods

Indeed, differences in results can be influenced by various survey parameters, including drone flight height, image overlap, or the accuracy of total station measurements. Each of these factors can impact the precision and the outcomes of the collected data. When choosing a method for measuring clay volume, it's important to consider these differences in results and select the method that best suits the specific project requirements.

5 CONCLUSION

Comparing measurement methods for calculating clay volume - polar method, GNSS and UAV surveying - provides insight into the different characteristics and advantages of each method. Polar method surveying enables precise terrain mapping with high accuracy. However, it requires more time in the field and data processing in the office. This method is suitable for detailed surveys of smaller areas. GNSS surveying offers an efficient way to collect data with high precision. GNSS technology allows rapid point location on the terrain, reducing the time required for surveying. Data processing can be performed using software applications. This method is particularly suitable for larger areas. UAV surveying allows fast and accurate data collection from the air. Drones capture a series of terrain photographs from various angles, which are then processed using specialized software applications to generate three-dimensional terrain models. This method enables the collection of a large number of points with high accuracy but may require appropriate training and equipment.

When considering the advantages and disadvantages of each method and taking into account factors such as data accuracy, surveying and processing time, complexity, and implementation costs, the choice of measurement method for calculating clay volume should be carefully evaluated. It is important to consider the specific project's requirements, the size of the area, and available resources. In the final conclusion, the selection of a measurement method for calculating clay volume should be based on accuracy, efficiency, time constraints, and project requirements. Each of the mentioned methods provides its own advantages and can be applied in suitable scenarios. The choice of which method to use depends on the specific project requirements, the desired level of accuracy, and the cost-effectiveness of the method. It's essential to consider these factors when selecting a measurement method, and to acknowledge that variations in results are expected due to the inherent characteristics of each technique.

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