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Drone Usage in Civil Engineering—A Case Study of the Pristina-Gjilan Highway

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Abstract

The use of drones in construction engineering has gained increasing attention in recent years due to its potential to revolutionize the industry. Drones, offer the ability to capture high-resolution aerial imagery and collect data that was previously difficult or impossible to obtain. The integration drones in construction engineering presents opportunities for accurate data collection, analysis and visualization, which can improve decision-making processes and improve project outcomes. For example, drones equipped with GIS technology can be used to capture high-resolution aerial images of construction sites, allowing engineers to monitor progress, identify potential issues, and make informed adjustments as needed. By harnessing drones, civil engineers in the civil engineering field can potentially optimize project planning, design and execution while minimizing risks and costs. The work of this topic examines the case of the use of Drones combined with GIS in construction engineering. During this study, aerial photography of a certain segment of the Pristina-Gjilan Highway was taken. The results generated by the processing of aerial photos have been compared with the project. However, further research is needed to fully understand the capabilities and limitations of these technologies in this specific context, as well as to explore any potential challenges and barriers to their widespread adoption.

Keywords

Drone, GIS, Engineering, Infrastructure, Aerial Images, Technology, Data Visualization

1. Introduction

Digital technology has recently taken a huge leap in every area of life. Regarding the infrastructure, it has always been difficult to monitor them. Digital technology has reached robotics, this situation has brought ease of work, but it has its pros and cons, as far as the development in the construction contest is concerned, in the research topic we will focus on how these digital devices help through different construction processes. The use of Geographic Information Systems (GIS) and drones in construction engineering, especially in the field of infrastructure engineering, has gained increasing attention in recent years due to its potential to revolutionize the industry. GIS provides a spatial framework to analyze and visualize complex data related to infrastructure projects, allowing engineers to make informed decisions based on accurate and up-to-date information. Drones, on the other hand, offer the ability to capture high-resolution aerial imagery and collect data that was previously difficult or impossible to obtain. While the benefits of using drones in civil engineering are well documented, there are still many aspects of their use that are not yet fully understood. Infrastructure projects involve complex systems, often spanning large geographic areas and requiring careful planning, design and management. The integration of drones in this field presents opportunities for accurate data collection, analysis and visualization, which can improve decision-making processes and improve project outcomes. For example, drones technology can be used to capture high-resolution aerial images of construction sites, allowing engineers to monitor progress, identify potential issues, and make informed adjustments as needed. Similarly, GIS can provide a geospatial framework for organizing and analyzing data related to infrastructure projects, such as site characteristics, environmental impacts, and transportation networks. By harnessing the combined power of GIS and drones, civil engineers in the field of infrastructure engineering can potentially optimize project planning, design and execution while minimizing risks and costs. However, further research is needed to fully understand the capabilities and limitations of these technologies in this specific context, as well as to explore any potential challenges and barriers to their widespread adoption. The purpose of this study is to analyze with a specific example the power of GIS and Dron in Civil engineering and specifically in the monitoring of the Pristina-Gjilan Highway. This will help in monitoring the works, reducing the possibility of corruption and in the end to draw up the archival project in a short time and with maximum efficiency.

2. Literature Survey

Recently, drone technology has begun to replace the old one, and this technology has brought not only ease of processes but also increased work efficiency. Despite the fact that for Kosovo it is a technology that is still not well usable around the world, its development has caused a great stir.

The integration of drones in infrastructure engineering signifies a pivotal shift in optimizing operations within various sectors. As evidenced by the accelerated adoption of drones in warehouses, the efficiency gains and cost reductions associated with aerial technologies are paramount [1]. Furthermore, the evolving concept of the Internet of Robotic Things (IoRT) presents a landscape where drones can seamlessly integrate with intelligent devices and collaborative robots, enhancing their functionality and expanding their potential applications in infrastructure projects [2]. The intersection of drone technology with the Internet of Things (IoT) opens up new possibilities for improved data collection, monitoring, and maintenance within infrastructure systems. As such, the strategic deployment of drones in infrastructure engineering is poised to revolutionize decision-making processes, enhance operational efficiency, and drive advancements in construction, maintenance, and monitoring practices. In their paper on "Application and requirements of unmanned aerial system (UAS) for construction safety" authors Masoud and Behzad focused on the fact that managers in construction companies despite all their achievements find it very difficult to list all the factors that affect the safety of the workers. Often they could not do the monitoring from the places where they work that are far from the construction site. Another reason is that some places are almost impossible to inspect due to the complexity and difficulty of the project area. So choosing the aerial method of unmanned drones would be an easy and perfect solution to these problems. Both industry professionals and university researchers are expected to benefit from the results of the study. These findings can help practitioners recognize the potential applications in which UAS can be useful in construction safety practices and the technical requirements and challenges of their use [3]. While the author [4] the use of new innovative technologies such as UAS in the construction industry is very necessary for the development of various aspects of the industry, such as safety. As the use of UAS on construction sites is relatively new, a number of issues can arise that affect on-site operations. This illustrates the importance of conducting in-depth research on the use of UAS in the construction industry. He reviewed 33 articles from the available literature on UAS applications and issues in the use of UAS in the construction industry and summarized them. Additionally, 9 applications and 10 issues were identified in the use of UAS in the construction industry. Another field of use of the UAS unmanned aerial system is the use of drones in monitoring the aging of building structures. German authors [5] taking into account all the atmospheric influences that affect building structures studied the monitoring of structures and the effects of aging by means of a drone. As a more complicated process, the authors have seen information acquisition and processing, that is, photographing and data processing, but according to them, the method will make a good contribution in terms of quality, safety and efficiency of work.

3. Materials and Methods

It is known that drones were created for military purposes and have a wide use in the army, but recently we have seen an increase in the importance of the use of drones in many different fields of science. Drones are being used for different purposes, the possibilities they have with different types of cameras and sensors make them important. The uses start before the function of taking pictures up to the purposes of photogrammetry or even extinguishing fires and the distribution of various orders, search and rescue missions, inspections and in different fields such as agriculture, forester, builder, etc. With the right technology for real-time monitoring, a person is conditioned to the possible use of drones in engineering, including many things in the field of engineering honor: environmental monitoring for the detection of leaks, surveying of rivers, difficult floods, traffic jams and individualization of accidents, structural ways of identifying mineralized liquids, and so on. In addition, they have to monitor and maintain pavements and highways, to control the construction process of equipment systems such as buildings and bridges through capturing videos and images from parts of the project site view [4] [6] [7] [8].

Kosovo is a small country and the use of sophisticated equipment is a little late. But the need to fight crime, corruption and normally increase the quality and safety of life make the adaptation of the latest technologies a necessary path. In this research project, the materials used, including a Phantom 4 RTK drone device, the Agisoft Metashape Professional data processing program and ArcMap desktop 10.5 for comparison of what was designed with the works that were executed in the examined segment of the Prishtina-Gjilan Highway.

The method used for the research is the mixed method, that is the qualitative and quantitative one, since in this topic, existing works of different global authors have been analyzed, but on the other hand, the collection of data from the field has also been analyzed. This topic will present the use of drones in road construction. The research was carried out based on measurements made with a drone in the "Pristina-Gjilan highway". The Drone Device Phantom 4RTK was used to measure data in the field. Data processing was done through the software Agisoft Metashape Professional. In the user manual of this program, the definition and function of this program are also given, where it is stated that Agisoft Metashape is a more advanced software solution, with the direction of photogrammetry at its final limits, while the entire system is designed to provide industry-specific results, relying on machine learning techniques for post-processing and analysis tasks [9].

Then, with the help of the ArcMap desktop program, the digitization and extraction of the results was done, which can be used for various engineering, management, monitoring purposes, etc.

Data Collection

The data of this research are primary (since they are collected directly from the source without having any existing source) and secondary, since the existing literature was also used. The research is both qualitative and quantitative.

Data collection from the field was done using aerial photogrammetric devices called drones (Phantom 4Rtk, is the model used for measurement). The processing and analysis of the results is one of the most important parts of this research. The processing of photogrammetric data was done using the professional Agisoft Metashape program, while the digitization and comparison of the results was done using the ArcMap 10.5 software.

Providing data from the field survey included all measurements that were made in selected locations within the territory of Kosovo. The measurements were analyzed in the Kosovo coordinate system. Field measurements did not have a high time cost despite the moderately large areas of the research areas; it is the data processing that required computer specifications and a long time for processing. In the Agisoft Metashape program, the processing for each case study took up to 4 hours, due to low computer parameters and a weaker graphics card.

The main theme is the use of Drones in road constructions process and specifically for monitoring and comparing the results achieved. So the specificity of this topic is how to obtain field information regarding the time planning of activities that are expected to be carried out at a certain time.

The method used to design the flight line is the "Linear Fight Measurement" method which automatically creates the flight field just by importing the axis line of the highway into the Drone controller.

Taking into account the basic principles of photogrammetry which are the care in the number of flights and the overlap of the pictures. With the new drone technology, this problem has been solved, but theoretically, we have to keep in mind that according to Karl Klaus, the author of the photogrammetry book, the horizontal cover should not be less than 60% and the vertical cover (between the routes)should not be less than 30% [10].

Altitude is another major flight plan consideration. Because the cameras on most drones have a fixed focal length (they are prime lenses, not zoom lenses), altitude directly affects image resolution. The result is a trade-off between image resolution and flight time. Low-altitude flights generate detailed images of relatively small study areas. Software updates could enable future flights to follow topography and maintain a constant altitude relative to the ground [11].

The condition of the drone was checked using the DJI GO 4 app to ensure it was in good condition before the mission. Firmware updates, drone calibration status, drone battery, telemetry and other parameters were examined using the DJI Assistant app. The first step of this process involves preparing the measuring instrument for flight.

Figure 1 is a tabular presentation of the process of preparing the drone for measurement and the relevant flight details.

4. Case Study "Prishtina-Gjilan" Highway

The case study includes a segment of the highway Prishtina-Gjilan, in cadastral zone Sllovi, Municipality of Lipjan. The examined segment is located in the village of Sllovi, Municipality of Lipjan.

Figure 2 shows the location of the study area in the local coordinate reference system called KosovaRef01. The study area is located in the central area of the Republic of Kosovo and includes a segment of the highway in the village of Sllovi.

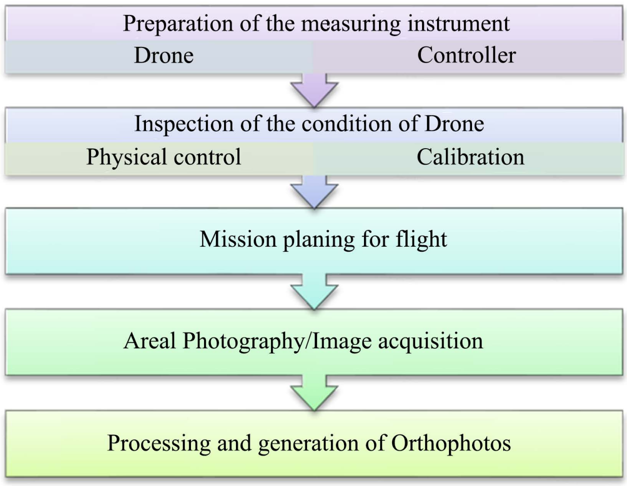


Figure 1. The list of work in the general methodology.

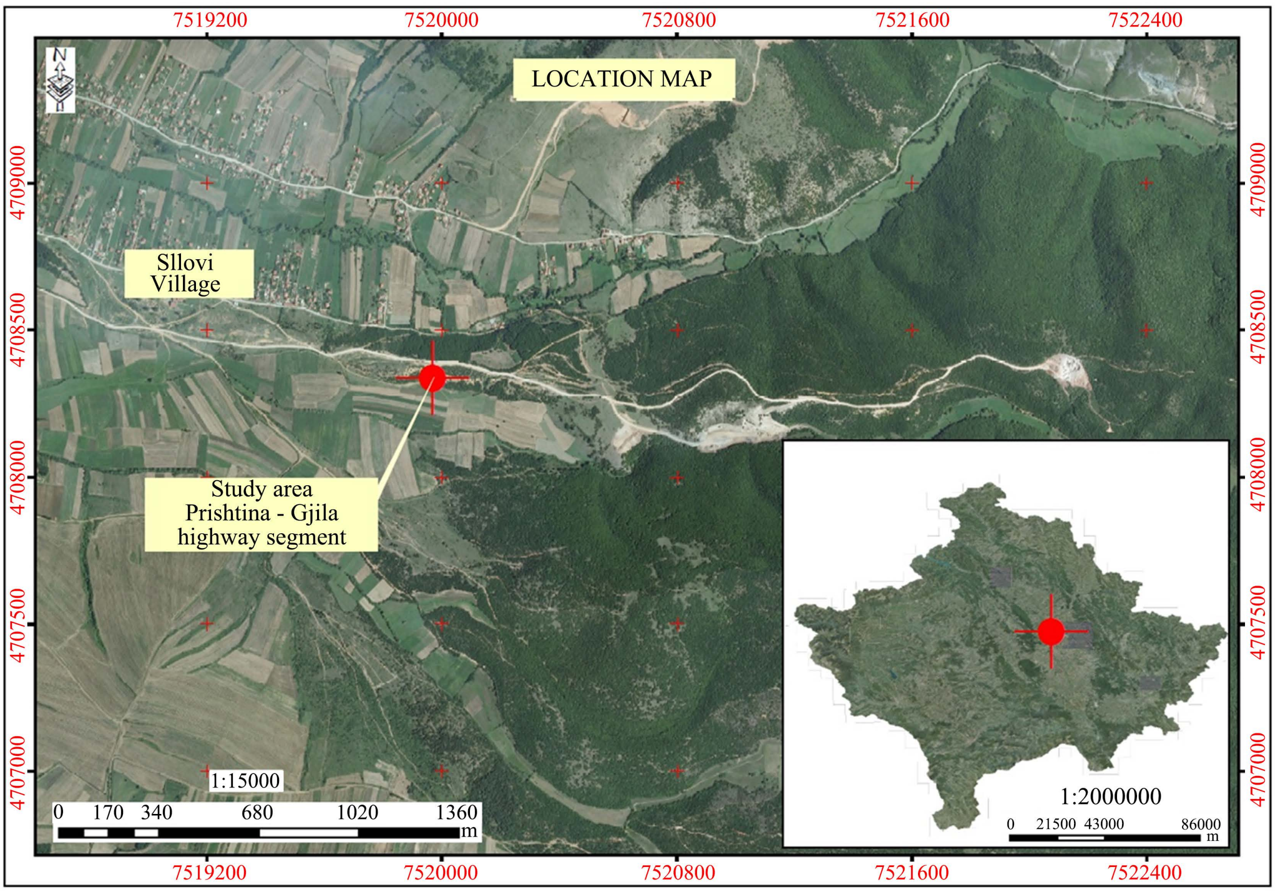


Figure 2. Location of the study area.

The purpose of this study was to determine all the changes that may have occurred during the execution of the construction works in the highway segment under consideration. For me, all the changes that have been made in the drainage channels, in the retaining and protective walls, in the body of the highway, in the placement of wells, in the transmission facilities, etc. All these are defined by the comparison of the project with the results generated by the processing of aerial photos. All flight details are listed in Table 1.

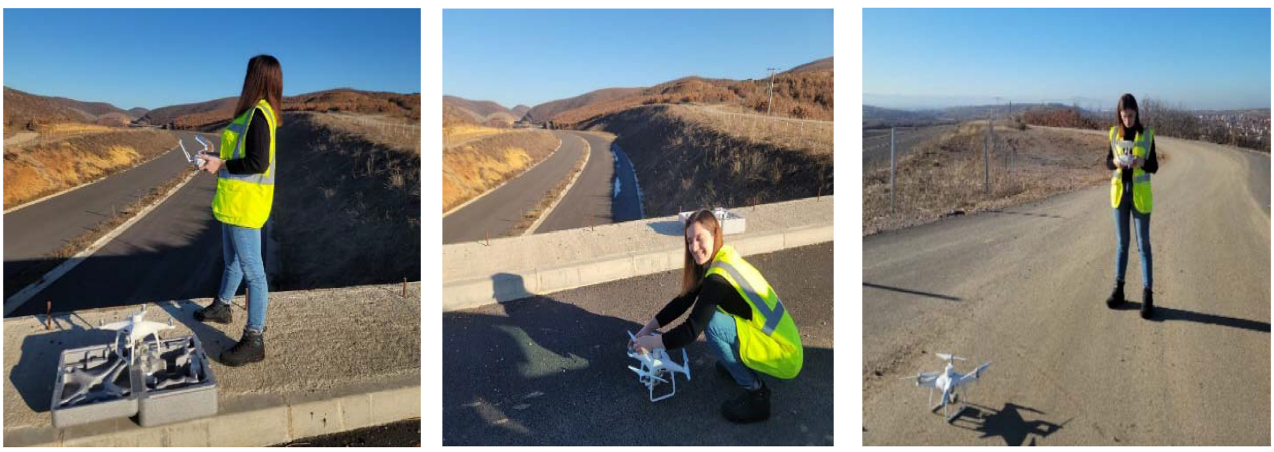
From the summary Table 1, it can be seen that the height from the place of departure of the drone is 80 m and that from the area where the flight is planned is 89.2 m from the design plane. The total number of flight lines is four routes on the total area of 0.515 km^2. The total number of photos taken by the process is 472 photos out of 560 projected.

Flight planning and model creation were done in the field and included several steps which are graphically presented in Figure 3. After checking the actual situation on the ground, we prepared the measuring instrument and then gave the flight commands.

With the help of the software Agisoft Metashape Professional, the processing of aerial photographs taken from aerial flights and the extraction of input data for processing in the ArcMap program was done. These data are from DTM, DEM, and PointCloud, etc. For processing, the procedure is the same as in the first case study and all the results of this procedure are presented below.

Table 1. Flight planning data table.

Coordinate system	Kosova Ref01 (EPSG::7392)
Number of flight routes	4 Flights
Horizontal and Vertical Overlap of Aerial Photos	Horizontal 70% Vertical 80%
Flight height from the departure point 100 m	80 m
Measuring height	82.9 m
Total number of photos in the area	560 photos
Total measurement area	S = 0.5105 km^2
The total flight time is automatically calculated from this set data	T = 23 min. and 36 seconds.



Visual survey of the terrain, preparation of measuring equipment

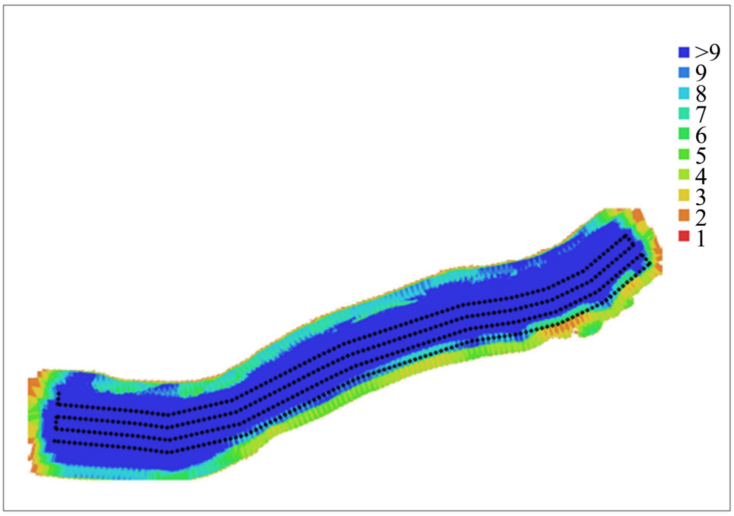
Assembling the Phantom 4rtk drone and starting the device

Planning the work, calibrating the device and starting the measuring process.

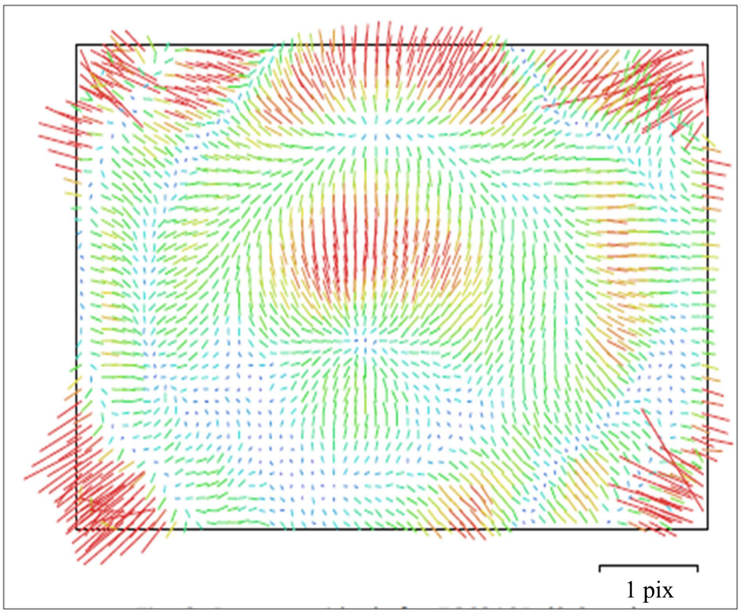
Figure 3. Photo from the measurement of the Prishtina-Gjilan Highway segment.

These photogrammetric processing results in a set of digital surface models with a resolution of 4.46 cm/pix and orthophotos. Vector and orthophotos are exported to other formats such as CAD and GIS formats.

The camera used for measurement is FC6310R (8.8 mm) in Figure 4(a) is shown the position of the cameras during the flight, from the measurement process; we obtained 472 photographs taken from 472 camera positions with a ground resolution of 2.23 cm/pix. In Figure 4(b) is shown the calibration of the camera generated for the given area. As can be seen in the outer parts of the polygon of interest, since there is no overlap of the flight, the color also starts to fade and the errors increase, respectively, the resolution decreases.



(a)



(b)

Figure 4. Camera locations (a) and image residuals for FC6310R (8.8 mm) (b) in highway flight mission.

Table 2 shows the calibration coefficients and the correlation matrix of the camera that was used for measurement. The average camera location error is 0.885455 cm in X (Easting), 0.689969 cm in Y (Northing) and 1.54358 cm in Z (Altitude).

The work process for extracting the product is a procedure that requires good computer parameters, especially good computer graphics card capabilities. Under normal working conditions, the processing process for PointCloud generation takes approximately 1.5 - 2 hours, always knowing that the computer parameters are moderately good.

PointCloud is generated with the high-quality template of the program. A total of 265,919,213 points in 3 classification bands were generated from the process. Figure 5 shows the point cloud of the flight area in a perspective view.

Because of this procedure, the necessary output for further study has arrived.

Figure 6 is the orthophoto and corresponding digital surface model produced by photogrammetric processing using Agisoft Metashape Professional. The 4.46 cm resolution orthophoto shown here is in the form of cells that are superimposed on the Google model that is also attached to the program. The results generated by photogrammetric processing are also available in other formats, such as shapefile and CAD data formats.

In Figure 6, it can be seen that the shape of the orthomosaic and that of the digital height model is a linear shape. This form includes elevations of the area

Figure 5. PointCloud of the "Pristina-Gjilan" highway segment.

Table 2. Calibration coefficients and correlation matrix.

	Value	Error	F	Cx	Cy	K1	K2	K3	P1	P2
F	3646.77	0.69	1.00	0.11	0.37	−1.00	0.98	−0.96	−0.37	−0.35
Cx	−16.2841	0.011		1.00	0.05	−0.11	0.1	−0.09	−0.13	−0.04
Cy	16.121	0.01			1.00	−0.37	0.36	−0.35	−0.12	−0.29
K1	−0.26698	0.0001				1.00	−0.99	0.98	0.37	0.35
K2	0.103151	8.0E−05					1.00	−0.99	−0.36	−0.35
K3	−0.0262086	3.1E−05						1.00	0.35	0.33
P1	−0.000514463	4.0E−07							1.00	0.01
P2	0.000191354	4.1E−07								1.00

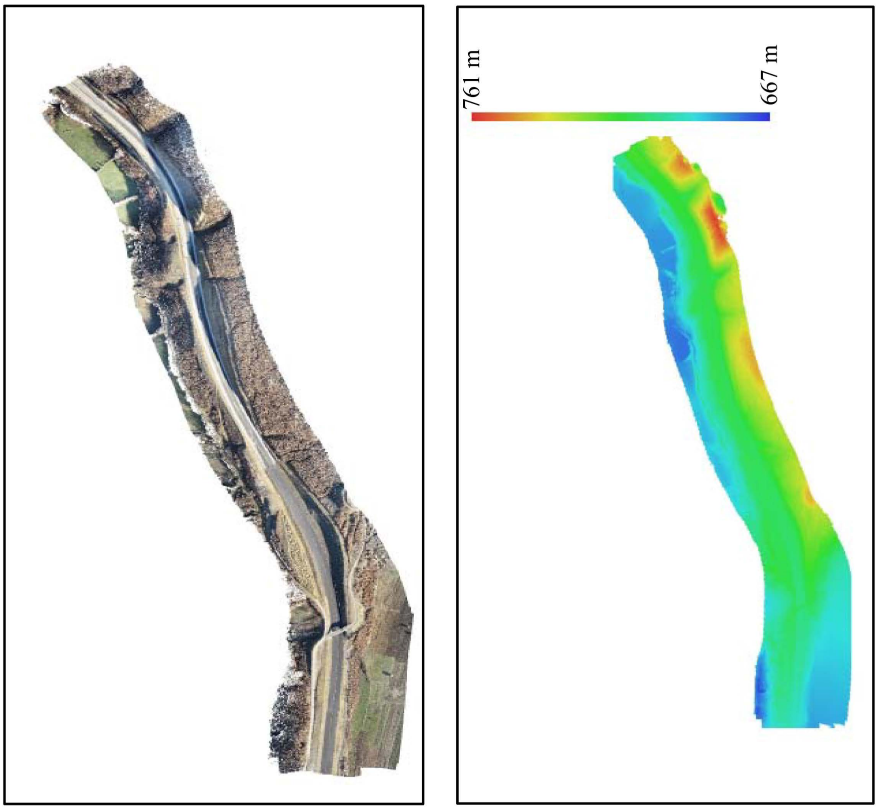


Figure 6. Orthophoto and elevation model of the study area.

ranging from 667 m above sea level to 761 m above sea level. The total area included is 0.515 km^2 and the width of the area is 40 m on the right and left sides of the highway axis, which is still under construction. This position was chosen for analysis because several different types of works are seen, starting from the highway body, concrete overpass bridge and the protection of the highway body through wall-gabions. Another reason that is added to this process is the possibility of project management through the drone and GIS in order to find if the project is moving according to the management plan.

In terms of infrastructure inspection, the main focus of drone use is clearly on obtaining data of the objects to be inspected. In order to fly around an object in general, a preliminary flight planning is needed, which as mentioned above in the new technology is done through software.

The analysis in GIS of this case study will consist of the comparison of the existing project and the comparison of the works with the project. The orthophoto generated with accuracy and resolution of 4.46 cm has detailed all the data applied to the project, starting from the canalization, the body of the highway, etc.

- **Channels for water drainage**

In the channels, it can be seen that the comparison between the orthophoto or DEM with what was designed has changes, which need to be archived. In Figure 7 it has been analyzed how the changes in the atmospheric water drainage channels around the body of the highway have been and it has been noticed that

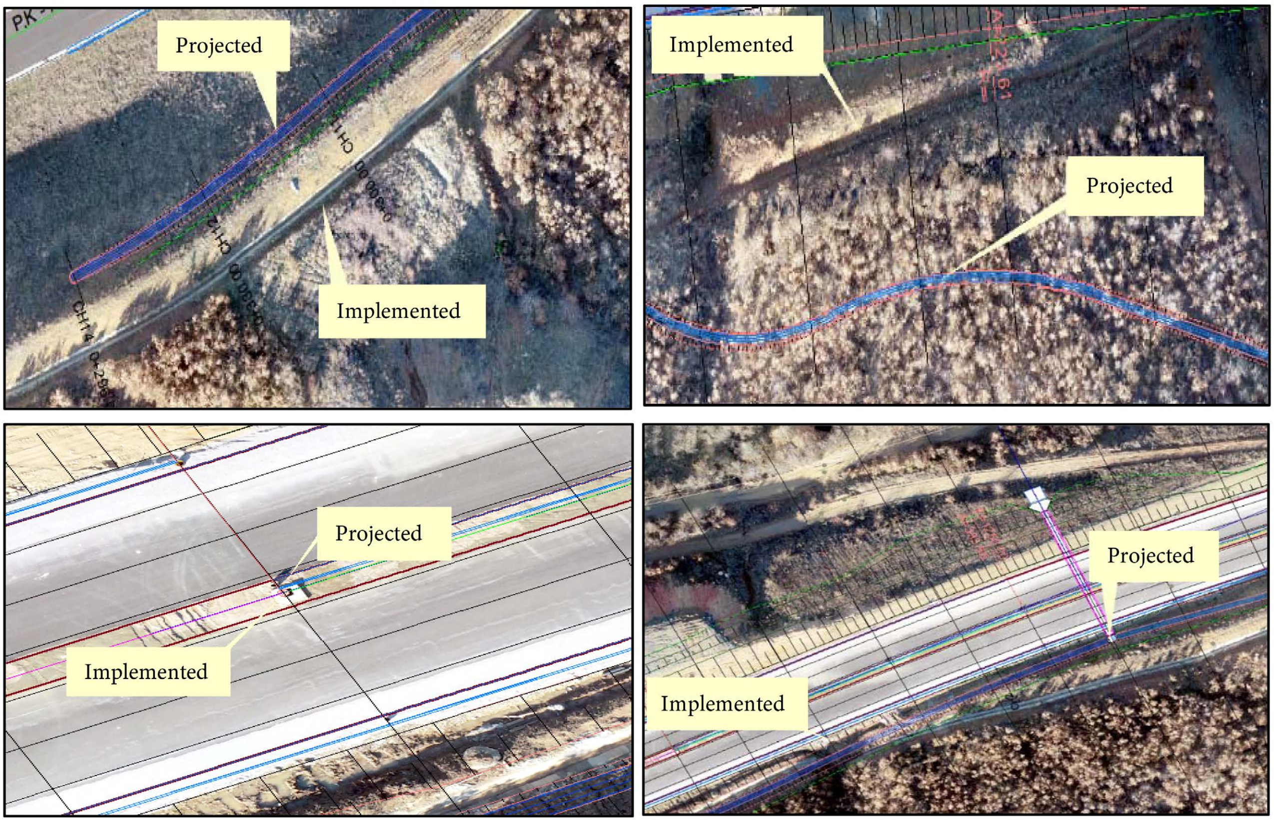


Figure 7. Identification of changes in water channels and wells.

almost in the entire segment under consideration there has been a change in the designed state with the executed state, these changes can have come as a result of:

- Measurement with low accuracy of the initial condition
- Bad design
- Geological formations and hydro-geological conditions of the area.

The other analysis in **Figure 8** shows some of the changes regarding the wells and water fountains in the project. The wells are generally in the same position as they were designed, while changes have been observed in the aquifers, which have come as a result of changing the lines of the canals.

- **Protective gabion walls**

In the segment of the highway under review according to the project, a protective wall with gabions has been designed at kilometer 12 + 655 to kilometer 12 + 915. The total length of this wall-gabion is 300 m, the real length determined by orthophotos turns out to be 172.6 m, but this process must be monitored until the closing of the works since the wall can be extended even more by reaching the projected values as is. As for the front part of the wall, since the highway is under construction, it can be seen that the wall has not yet finished construction. The height of the wall with gabions turns out to be 14.3 m. This height is visible, since the base, which coincides with a row of gabions, is not included in the impossibility of measurement (**Figure 9**).

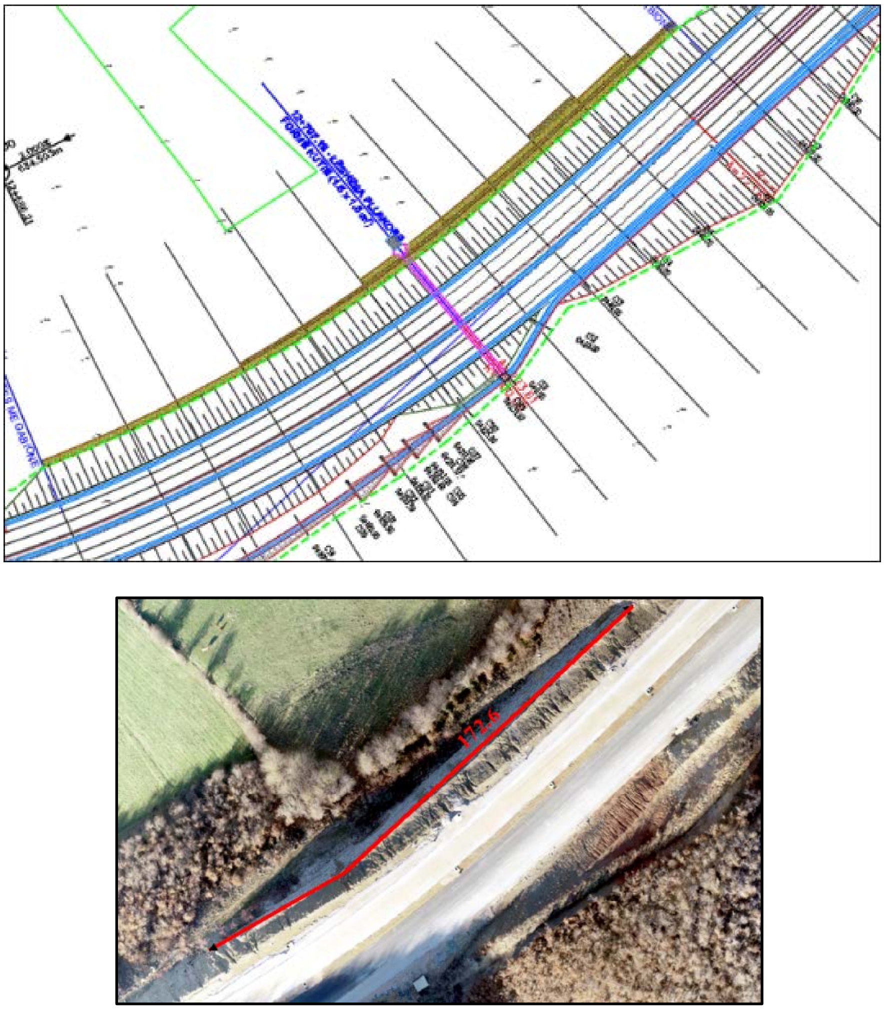


Figure 8. Designed gabion wall and Top view of gabion retaining wall, its actual length.

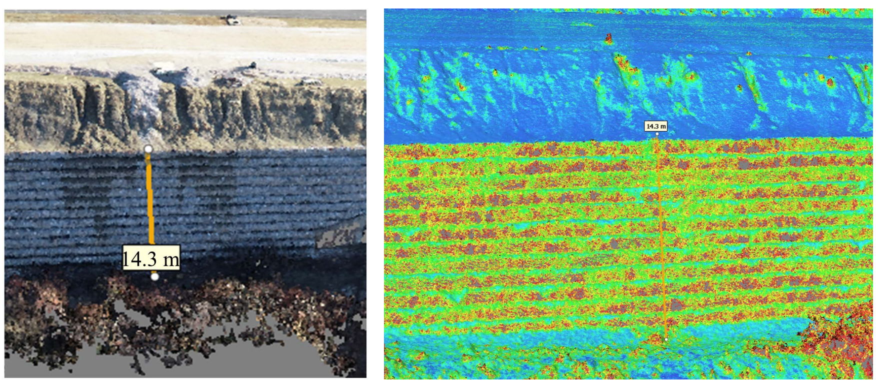


Figure 9. Maximum height of gabion.

From the processing process, some parameters of the bridge were determined, from which it results that the length of the bridge is 53.5 m, the width of the passage is 6.0 m, and the total width, including the sides, is 8.8 m (**Figure 10**).

For other highway objects, one of them is the bridge, a flight planning is necessary only for the bridge, in order to accurately define all its parameters.

Figure 10. Geometric planimetric parameters of the bridge.

5. Conclusions

This case study supported the use of drone in civil engineering in the field of construction monitoring. It was seen that the segment under consideration on the highway has undergone changes with the project, which are also presented above. In the case study, only one topic of monitoring and comparison through GIS is presented. However, it shows that the same way of monitoring can be used in any construction development.

From this case study, we get:

- 3D model of highway segment measured by drone, processed with Agisoft.
- Orthophoto generated from measurements with a resolution of 4.46 cm.
- Determining the changes between the project and what was executed in the field.

As a conclusion of the difference of the above-mentioned changes, the archival project of the highway including all the changes is documented and drawn up.

This method of monitoring and detecting changes can be used on any type of object. Mainly it would be a great help in monitoring unauthorized constructions in residential centers.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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