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Usage of unmanned aerial vehicles on highways and application areas: a case study of Kozan Mansurlu Road

Fatih Tükenmez *[1]

[1]*General directorate of Highways, 5th district Office, Mersin, Türkiye, f.tukenmez@hotmail.com*

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Abstract

Unmanned aerial vehicles (UAVs) are fixed or rotary wing aircrafts that can be guided by modern remote-control systems that can fly without a human being. It is important that UAVs, which have had many uses recently, are used on highway engineering services as well. It is desired that the accuracy of the numerical height model should be high in determining the horizontal and vertical geometry of the highway project and calculating the amount of cubage based on road construction costs correctly. In this context, the usage of UAVs on landslide prevention projects and the production of current maps of intersection areas is also important on highways. In this study, the usage and application areas of UAVs on the highways have been mentioned. It has been observed that the results obtained by comparing the landslide region, numerical land model obtained from Kozan Mansurlu Road Landslide Region, numerical map production model with the terrestrial classical methods and numerical land model have sufficient accuracy and sensitivity in the mountainous land region.

1. Introduction

Highway is a land strip that allows traffic flows including vehicle and pedestrian, and bridge, tunnel, viaducts, protection structures (retaining and shoring walls) which are located on it. The roads in the highway network are classified as State, Province and Highway. State roads are roads that connect provinces, provincial roads connect districts, and highways are roads with high geometric standard access control.

Base maps are large-scale maps used in road projects as well as in other engineering fields. The base maps used for highway route projects are Energy Transmission Lines and strip-like maps showing streams, hills, canals, roads, energy transmission lines covering a corridor of approximately 200 m. In addition, they are produced to be used in intersection projects and landslide prevention projects, which are local application areas on highways.

All these route maps were produced using classical methods (measurement, calculation and drawing) by the Highways survey teams, which were expressed as entrusted in previous years. As a result of developing technologies, these maps started to be produced digitally with the classical terrestrial method, by means of tenders, using GPS measurement techniques. In recent years, existing maps have been produced photogrammetrically by tender, especially on routes of 30 km and above, taking into account the topography of the land.

Digital Terrain Model (DTM), Digital Elevation Model (DEM), Digital Surface Model (DSM), City Maps, Geographic Information System (GIS), 3D modeling of areas can be given as examples of UAV usage. The creek, ditch and slope which are defined as the critical land section on the base maps for the highway projects. The precision of the DEM is important for the sections to reflect the real terrain and for the correct and calculation of soil volume calculations. The DEM produced with UAV technology gives a high accuracy result, as seen in this study.

Unmanned aerial vehicles (UAVs) are fixed or rotary wing aircraft that are the modern measurement systems, which can fly without a human on them, and can be directed by remote control. There are tools that can be used by civilian users in many sectors such as construction in the real estate sector, fields, photography, agriculture, mining archeology, agriculture, geological applications and photogrammetric studies.

Two decades ago, different surveying techniques such as total station and kite were used to model the terrain [1]. Nowadays, UAV can be controlled via a smartphone easily. UAVs are used in risky situations without endangering human life and in inaccessible areas (heavy forest areas, etc.) where there is no manned flight opportunity and flight permit cannot be given. In classical method robotic total station was used to create DEM [2]. Today, a UAV can easily produce DEM [3].

UAV has been used in many engineering projects such as landslide [4], rockfall [5], shoreline detection [6], cultural heritage studies [7-13], Energy transmission line detection [14], vegetation detection [15], and tree detection [16] and volume calculation [17-19].

UAV enables to produce maps in a short time at low cost, especially on the routes where mountainous and dense forest areas are hit on the highways. UAVs are categorized in various ways depending on their capabilities, size, or the tasks they perform. There is no specific standard for the classification of UAV systems. Since the systems are generally designed to fulfill various tasks, the limits of the classification change according to the developing technology.

Military UAVs are vehicles used during the performance of basic military missions such as reconnaissance, surveillance and intelligence that serve military purposes for our national security. Civilian UAVs are the preferred aerial image acquisition tools in various fields in recent years, and they have been frequently used in survey engineering in recent years.

Ten years ago, terrestrial photogrammetric methods were used in many engineering applications [20]. UAVs are preferred because they can make measurements in risky areas and where people have difficulty in local access thanks to the Digital Camera and GPS-GNSS systems placed on them. The data obtained is fast, economical and close to classical methods in terms of measurement accuracy [21-22]. When the measurements made with UAVs are evaluated in terms of sensitivity, it is seen that it has a place to fill the gap between classical terrestrial measurement methods and classical aerial photogrammetry.

With the Kozan Mansurlu Road landslide prevention project study, it is aimed to compare the DTM produced by the UAV with the existing DTM, which was previously produced with the classical terrestrial method, and to use it effectively on the highways.

2. Material and Method

The UAV can be used mostly in intersection projects, landslide prevention projects, the production of Digital Base Map and DEM for highway projects. In this study, the creation of a digital base map and DEM, which will be the basis for the Kozan Mansurlu Provincial Road landslide prevention project, is mentioned.

2.1. Study area

In this study, the landslide section (Adana-Kozan), Ayr.-Mansurlu Provincial Road, islocated between Km: 50 + 160- 50 + 600. The section for producing the base map using UAV is approximately 1 km, between Km: 49 + 800- 50 + 850 (Figure 1).

The aim of Kozan-Mansurlu work is to produce digital maps of the landslide area with the photogrammetric method using a UAV (drone). The relevant area is located in the Marankeçili locality, approximately 30 km northwest of Kozan district of Adana province (Figure 2).

Figure 1. Google Earth image of the project area

Figure 2. Orthophoto map of the project area

2.2. Data

Within the scope of producing the base map of the road with the terrestrial method by our Regional Directorate without leaving the land, a total of two polygon points (P33, P27), at the beginning and at the end of the Project, among the polygon points whose facilities and measurements were made beforehand, as a reference for the new Ground Control Points (GCP) to be laid within the scope of the flight (Table 1).

DJI Phantom 4 Pro model drone (Figure 3) was used for flight. The drone has an integrated 20 MP camera and axis gimbal. In this way, the camera angle always remains constant during the flight.

The flight was made from approximately 150 meters with 80% transverse and 60% longitudinal overlap, and a total of 288 aerial photographs were obtained.

Table 1. Coordinates of polygons (ITRF-96, DOM 36, 3°, Epok:2005)

Poligon	Easting (m)	Northing (m)	Elevation (m)
P.27	465360.491	4170623.615	873.500
P.33	465371.462	4171554.747	1000.408

Figure 3. DJI Phantom 4 Pro

2.3 Method

Within the scope of the project, fourteen new GCPs were established. While constructing the point facilities, attention was paid not to choose places such as the bottom of the tree, in front of the wall, in front of the building, and open areas that were easily selected from the air were preferred. While point facilities are being built, it is aimed that the distance between each other should not exceed 300-400 meters (Figure 4).

The flight plan was prepared and implemented as a single block. While preparing the flight plan, it is necessary to consider the structure of the terrain and the distribution of GCPs. For example, in this study, the flight direction was chosen as north-south. The most important reason is to reduce the possible risk by flying parallel to the mountains and hills in the field and to minimize the flight time that will arise. While constructing GCP facilities, care should be taken to distribute them as homogeneously as possible on the flight area. If there is more than one block at the beginning and end of the flight columns, GCP must be installed at their intersection.

The obtained aerial photographs were transferred to the computer and overhead triangulation, balancing and orthophoto production processes were completed using Agisoft Metashape 1.5.2 software.

The primary step on the software is to collect the point cloud, so that the common areas in the photo and column overlays are matched with each other with the help of pixels and the needed point cloud is obtained (Figure 5).

Then, by marking the real places of the GCPs on the photograph, the positioning of the photographs is ensured (Figure 6).

After GCPs were marked on the pictures, the balancing process was performed and the coordinate, height and rotation (omega, phi, kappa) values of the pictures and the camera calibration information of this balancing were obtained. With the help of this data, the pictures were introduced to Erdas Imagine software and the evaluation process was completed by the photogrammetry operators. Before starting the valuation, all GCPs were compared with their real values and their values from stereo and checked. At the same time, the model and column transitions were also checked in this way, and then they were digitized safely.

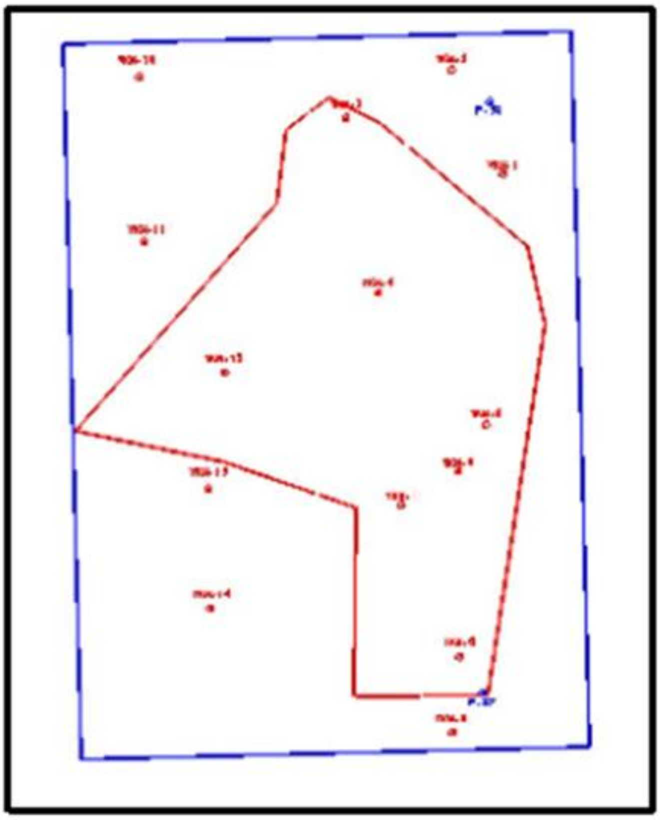

Figure 4. Ground control points

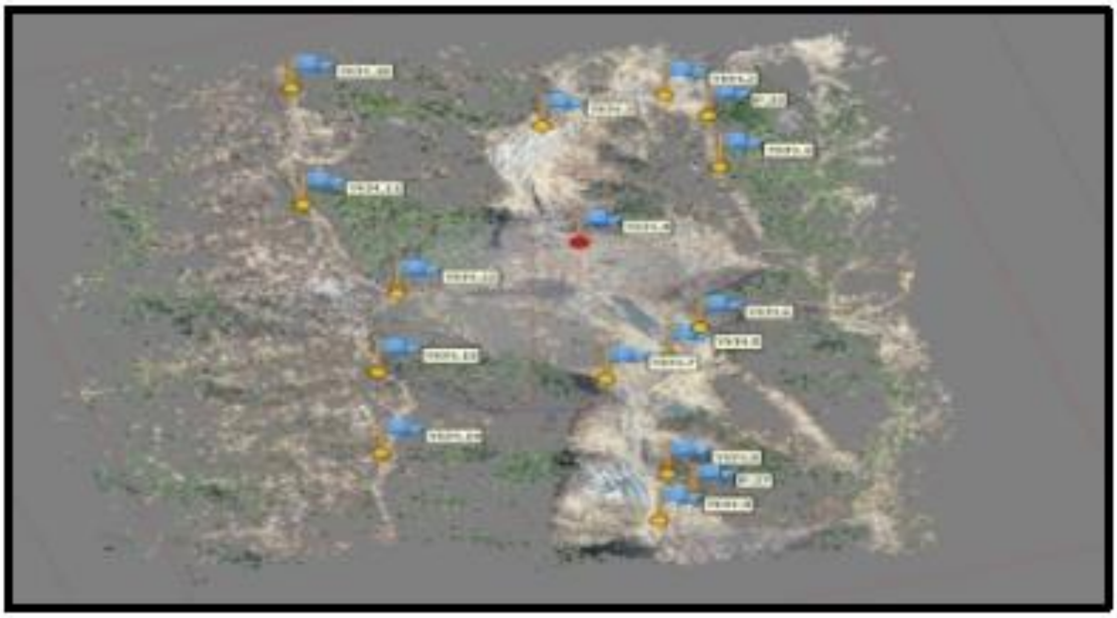

Figure 5. Point cloud of the study area

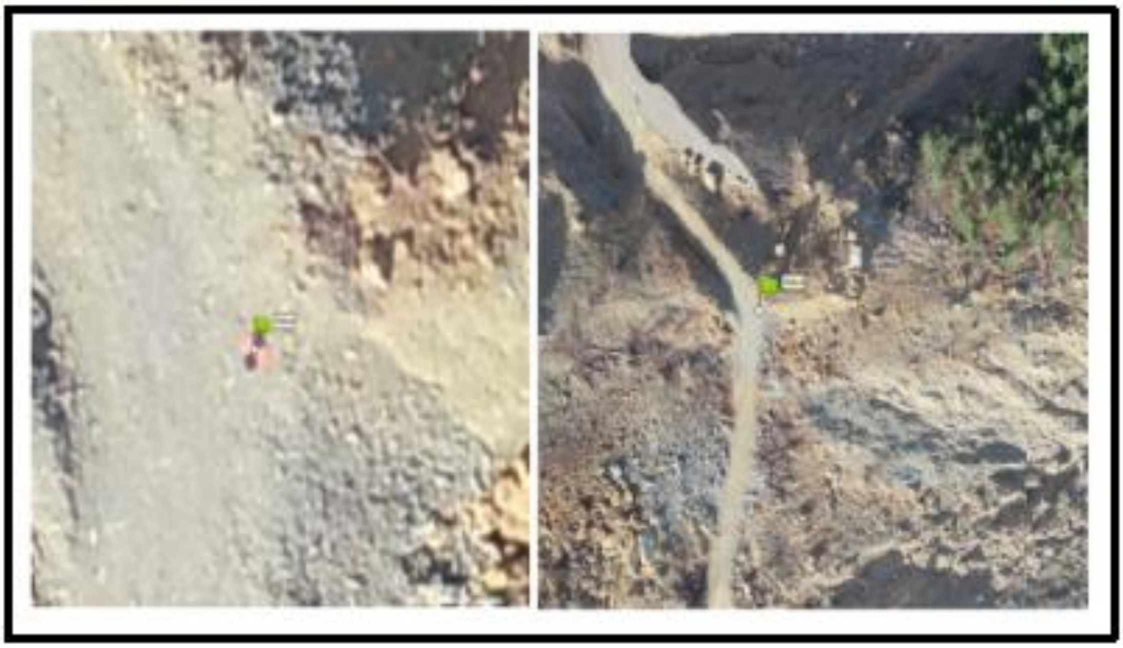

Figure 6. Ground control points in the field

3. Results and conclusion

The elevations of five points on the Digital Base map, obtained by using Microstation software, were read through the digital terrain model (DTM) (Figure 7). These points were compared with the DTM obtained in Netcad program (Figure 8) of the existing map of the region, which was previously produced with the terrestrial classical method. The differences between the heights of the points between both models were calculated and it was seen that the results were within the error limit (Table 2).

- When the results obtained considering the study area are examined, it shows that the use of UAVs on highways is a sensitive and appropriate method, especially in mountainous and inaccessible areas.
- The Kozan-Mansurlu road and the landslide area in the study area have mountainous terrain and the road standard is low. In such areas, if the base maps for highway route projects are produced using classical (traditional) terrestrial methods, it creates a danger in terms of life and property safety, especially in mountainous and inaccessible areas, and requires time loss and high cost.
- At the end of the project, UAVs can be used in the preparation of the final projects of the highway projects whose production is completed according to the project.
- It should be preferred to produce maps with UAV technology in order to ensure life safety due to the heavy traffic in the intersection areas, especially in urban intersection designs.
- Study example, in the Kozan Mansurlu Road landslide region, it is seen that the difference in the terrain elevations on which the control measurement is made on the digital terrain model produced by using the UAV technology and the classical terrestrial method is in the range of ±5-10 cm on average, and it is an acceptable high-accuracy result according to the highway map technical specifications.

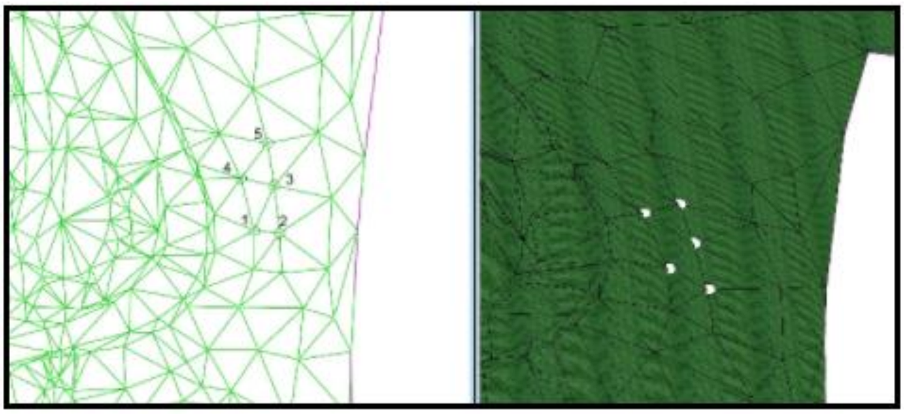

Figure 7. Digital elevation model obtained from MicroStation

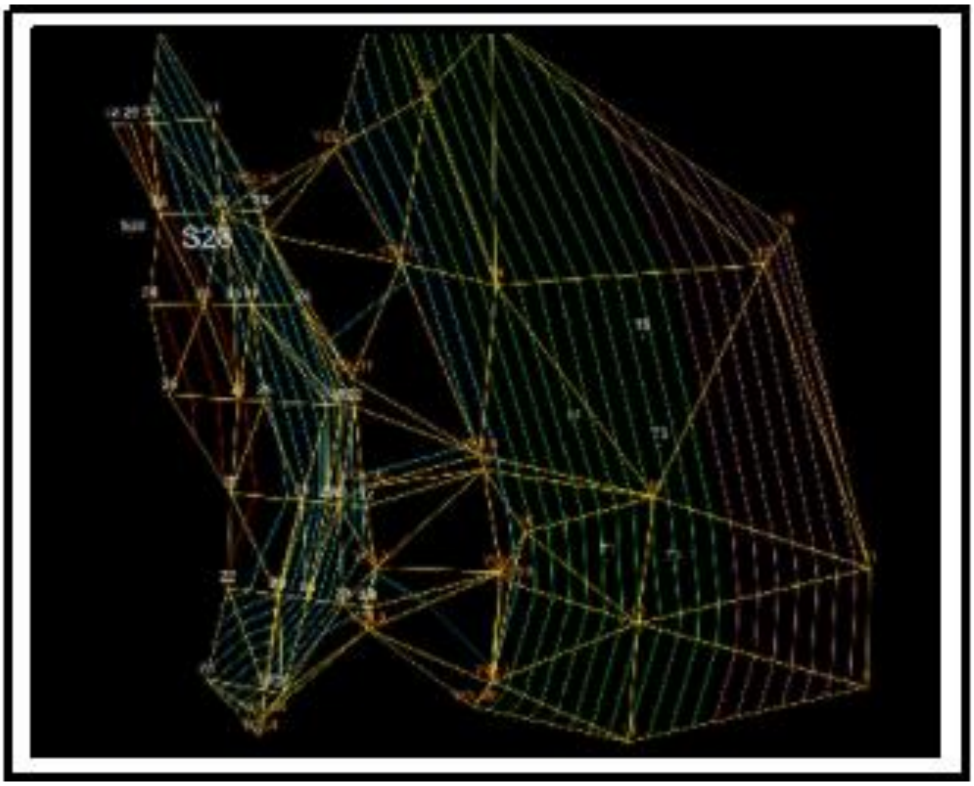

Figure 8. Digital elevation model obtained from Netcad

Table 2. Comparison of digital elevation models

Point	Y (m)	X (m)	H (avg) Terrestrial	H (avg) UAV	Difference (m)
1	465415.65	4170980.11	920.44	920.34	0.1
2	465420.45	4170979.59	917.063	917	0.063
3	465419.42	4170988.44	916.74	916.74	0.06
4	465413.2	4170989.84	920.94	920.94	0.08
5	465418.15	4170996.36	916.13	916.13	0.09

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Conflicts of interest

The authors declare no conflicts of interest.

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