

Risk Management Model of Unmanned Aerial Vehicles Usage in Geoscience Applications

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ABSTRACT:In this study, it was aimed to identify risky situations that would be faced during the use of unmanned aerial vehicle (UAV) systems in engineering and geoscience applications. And, in this respect, it was aimed to establish a suitable risk management model that would be taken into account during the use of UAVs. The focus was on the use of UAVs in engineering sciences especially in measurement and mapping, not on their use for military purposes. To that end, a risk analysis methodology was established, and a general risk management model was developed with the help of that methodology, as part of all flights to be performed using UAVs — the use of which has increased rapidly in engineering, design, modeling and follow-up over the last decade

KEYWORDS:Unmanned Aerial Vehicle (UAV), Geoscience applications, Risk management

I. INTRODUCTION

Unmanned aerial vehicles (UAVs) are motorized or non-motorized aircrafts that operate according to automatic or semi- automatic flight principles. UAV has been developed from the second world war to the present day and has been actively involved in various fields of producing many kinds of 3D models such as geosciences, architecture, natural life and environment, earthquakes, disaster management and planning, water management and forestry, photogrammetric evaluation moreover in parallel with the technological developments in recent years, the field has started to be widely used.

Digital cameras used in UAVs are able to produce 3-dimensional (3D) dense point clouds, digital surface models (DSMs) and orthophoto images of objects or sites, thanks to their high resolution, 4K and almost error-free coordinate processing technologies. Easier and more accurate analyses of the difficulties encountered in measuring and calculating activities lead to the use of UAVs in engineering works even more effectively.

There are risk factors arising from the nature of the work in every engineering discipline. In the most general sense, a risk is defined as a function of the potential for failure to achieve a targeted outcome, or the probability of occurrence of an undesirable event and the severity of the outcome in the case that it occurs [1,7,17,16]. There are three main components of risk: An event that may occur, that is, an unwanted change; the probability that this event occurs; and the impact that this event makes when it occurs [12]. Considering these three components, during the use of UAVS in engineering studies, especially in geosciences, the possible risk factors should be minimized, and it should be ensured that the tasks to be identified are fulfilled.

II. RELATED WORK AND CLASSIFICATION OF UNMANNED AERIAL VEHICLES

The term unmanned aerial vehicle (UAV), as a name, covers all aerial vehicles that can fly without human presence and can be controlled in the air. In computer science and in the circles interested in the subject of artificial intelligence, the term UAV was given various names such as remotely piloted vehicle, remotely operated aircraft, remote controlled helicopter, unmanned vehicle system, and model helicopter. UAVs first appeared for military purposes, and especially after the Second World War, the fact that certain countries needed unmanned aerial vehicles that could enter enemy areas or high-risk areas and return without being noticed was one of the most fundamental elements that initiated the development of UAVs [9]. However, the use of UAVs in virtual measurement was first performed in 1979 with the

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implementation of the aerial photography method using an UAV. During the implementation, 1:1000 scale photos were taken. The speed of the UAV was too fast to get a proper photo, so the results were not satisfactory. A more advanced navigation system was integrated into the vehicle after the flight. In this way, successful photographs were taken at an elevation of 150 meters and with a speed of 40 km/h. This achievement has begun to expand the areas of use of UAVs. Wester-Ebbinghaus developed the first helicopter models in the early 80s because the vehicles needed to hover stationary in the air in order to be able to fly with less vibration, to manoeuvre better and specially to collect impeccable and precise data depending on the needs [10].

Remote controlled helicopters and model helicopters are classified as mini-, short-, and medium-distance UAVs by the Association for Unmanned Vehicle Systems International (AUVSI), according to their size, durability, distance and flight altitude. UAVs like Pegasus are defined as long-lasting UAVs [10]. The classification of long-lasting UAVs made by AUVSI into a single category is given in Table 1.

Table 1. Classification of unmanned aerial vehicles

Category	Weight (kg)	Range (km)	Flight Altitude (m)	Endurance (hours)
Micro	<5	<10	250	1
Mini	<25/30	<10	150/250/300	<2
Short distance	25–150	10–30	3000	2–4
Medium distance	50–250	30–70	3000	3–6
Altitude	>250	>70	>3000	>6

The virtual measurements through UAVs have become increasingly widespread and entered the fields of geology and mining. Although the most common areas of use have especially been the planning of mines and area and volume calculations of stockpiles, they have begun to be used frequently in blasting operations, mapping and monitoring of environmental impact, slope stability and occupational safety, and providing data to 3D mining programs especially in the last 10 years.

III. USE OF UAV'S IN ENGINEERING WORKS AND ADVANTAGES OF UAV'S

The first step in the use of UAVs in engineering studies begins with the scanning of the relevant project site or object and the acquisition of two main groups of data. These groups of data are orthophotos and digital elevation models. With the software developed for UAVs, these two steps take place under the control of the software to be preferred. The goal of these software programs is to make the data collection step for virtual measurement quick and easy through the customized user interface. The UAV sets its route, angle and number of rounds under the control of the software. The next part involves the merging of the data collected and the transformation of the data to be suitable for 3d software programs. If desired, this application can also be run by controlling it manually.

In the second step, by using the software specific to UAVs, the data — the amount of which is adjusted depending on the magnitude of the work to be done and the quality of the measurement — are merged and their geo-referencing is performed. At the end of this stage, a complete model is obtained. Depending on the software used, a solid surface model or a point cloud is created. Based on the aligned point clouds, it is possible to generate a digital terrain model (DTM) and orthoimage[13]. These point clouds are processed in a desired 3D software program with coordinates and are actively used especially in geosciences and architectural areas for precise calculations and measurements.

Today, thanks to the recently developed UAVs and the GPS systems — that are integrated with the precision imaging devices placed on these vehicles — the work areas where unmanned aerial vehicles are preferred are rapidly increasing

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(Figure 1). Studies carried out with the help of UAVs catch up with the terrestrial photogrammetry in terms of precision and can be applied in many different areas, as UAVs can complete work in a short period of time [10]. Many researchers have used unmanned aerial vehicles effectively in various areas and obtained positive results, including Niethammer et al. (2009) in the field of monitoring and obtaining high-resolution images of landslides, Wing et al. (2014) in the mapping of surfaces of forest lands, Döner et al. (2014) in the use of UAV images for mapping studies, Mases et al. (2015) in the use of UAVs for communication purposes in large-scale disaster studies, Akgül et al. (2016) in generating a high-precision numerical elevation model and its use in forestry areas, and Yakar and Mirdan (2017) in the modeling of historical monuments. In Figure 2 below, the distribution of 1000 UAV applications carried out between 2015 and 2016 are given according to their purposes. As the figure shows, a great deal of the applications carried out in recent years by using UAVs have gathered in areas such as aerial photography, aerial survey, aerial inspection and agriculture. For this reason, it is important and necessary to know and reveal the risks of applications of UAVs which have found so many areas of use in addition to military applications.



Fig. 1. Used unmanned aerial vehicle

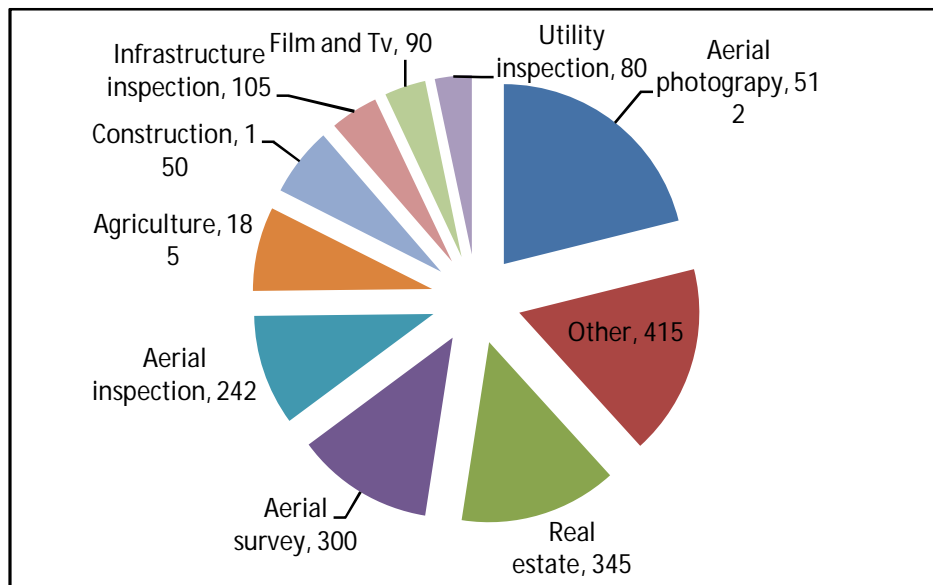


Fig. 2. Distribution of 1000 UAV applications carried out between 2015 and 2016 according to their purposes

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IV. RISK AND RISK MANAGEMENT IN UAV APPLICATIONS

The key to successful risk management is an early identification, a planning, and a determined implementation. A good planning makes it possible to develop risk identification, assessment and response through a comprehensive and iterative approach. Risk management is a management discipline in itself, but it is not a magic management discipline that will completely eliminate ambiguities and risks; it is a discipline that enables systematic assessment of potential risks and reduces the effect of potential damages to make decisions based on data, and should be implemented in a holistic manner with other disciplines [6,11].

The risk management process consists mainly of five steps. These steps can be listed as risk identification, risk assessment (risk analysis), risk mitigation and risk decision making, implementation of control measures, and inspection and evaluation [3,4,5]. Risk identification and assessment are performed in the first two stages of the process. In the first stage, any dangerous situation that can be encountered during the application is detected, and the effect of each danger is identified. The variables of the risk analysis stage are probability and effect. In the consequent steps, an effective management of risks is performed.

It is equally important to determine the magnitude of the potential effect of a danger or dangers on humans, equipment, or the work that is being done. The effect should be assessed realistically based on the worst possible outcome. After the risk-related probability and effect are assessed, a risk matrix is created, and the level and magnitude of risk, in other words, the severity of risk is found [11].

Risks That May Be Encountered in UAV Applications

According to the international definition of ICAO, an event where an aerial vehicle crashes, gets broken, injures people, kills people, or damages other aerial vehicles, public or private goods or property while the vehicle is run, moves on the ground, and during flight is called an accident investigation [6]. Aerial vehicle accidents are classified into four severities of damage, including "major damage," "partial damage," "minor damage," and "unclassified damage," depending on the damage that occurs [19]. According to the rules of flight safety, factors affecting the occurrence of accidents are represented by the 5M model as human, machine, management, task and environment. The examination and evaluation of these factors present the effects of human, machine and/or environmental conditions that cause accidents. In this context, some of the risks that may be faced especially in the use of UAVs in the engineering operations are as follows:

- The loss of the pilot – UAV connection, leading to the loss of control of the vehicle
- Losses of control caused by high-voltage transmission lines or power transmission lines
- Errors originating from the software used
- Mistakes during the preparation of flight plans
- Losses of control caused by adverse weather conditions
- Device battery problems

Based on such reasons, the occurrence of undesirable accidents during flights and possible accidents should be classified in different damage groups.

In the field studies conducted with UAVs, especially for geosciences, the most important factor that poses a risk other than the human and machine factors is the environment factor. Environmental factors (wind, lighting conditions, high-voltage transmission lines, and so forth) during the aerial imaging of the sites to be examined should be carefully examined, and their observable adverse effects should be avoided.

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Vol. 7, Issue 10, October 2018

The Proposed Risk Management Model

Considering the risks that are counted above and many more which can be counted further, it is possible to classify the dangers that may be encountered in the research, measurements and calculations that would be carried out by using UAVs. These can be classified as dangers originating from the human factor, dangers originating from the device factor, dangers originating from the work and/or task factors, and dangers originating from environmental factors.

In order to identify these dangers and to reveal the risks that may be caused by the dangers, the main framework of the risk management system was created for UAVs by working together with groups from different engineering disciplines based on about 250 hours of flights. The framework is briefly summarized in Figure 3.

According to the steps of the risk management system that is tried to be summarized in Figure 3, first, a site assessment study is started based on the nature of the work to be done. The sites or objects to be mapped are identified, and the process is initiated by calculating the required flight duration. Next, the possible dangers during the specified flight and the sources of these dangers are determined (humans, devices, environment, and so forth). In the second stage, the

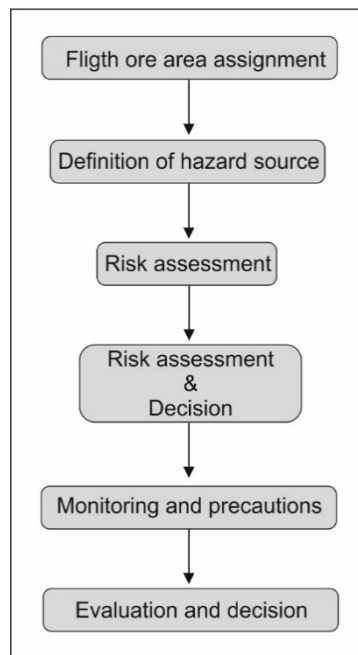


Fig. 3. Risk management model in UAV's

impact of the dangerous situations is assessed, and the severity of their risks are determined. The next stage is the risk assessment and decision stage. This is the stage in which the decisions are made to identify the ability to control possible risks, to avoid the risks, or to take the risks. Based on the decision given after this stage, the risk levels are assessed and monitored. At the last stage, the risks should be inspected, they should be assessed, and it should be ensured that the new experiences that have been gained are used.

As part of the risk management system briefly outlined above, in studies of geosciences carried out by using UAVs, a working environment is created, where the intended site data is collected in a time frame that is about 10 times shorter compared to the time it takes for measurements and mapping carried out through classical methods. And, in terms of possible risks, a working environment is created, which is almost a hundred percent safe.

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V. CONCLUSION

The use of unmanned aerial vehicles especially in other branches of geosciences, architecture, agriculture and engineering has increased gradually over the last decade and has become almost fifty percent compared to the area of use in all sectors around the world. The fact that measurements, modeling and other calculations carried out by using UAVs —which are increasingly used in the disciplines related to geosciences (map, geology, mining, and so forth) — take place in a much shorter time and more reliably than those in classical methods makes the use of these devices even more appealing.

The number and places of use of UAVs are increasing more than ever. In order for UAVs to be used more safely and more efficiently as in every sector today, the risks during use should be determined according to the schema specified in Figure 3, and these risks should be managed. In this study, the risks involved in the use of UAVs in engineering applications were identified, and a sample management model was developed to eliminate or reduce these risks.

According to the model developed, in flights for different purposes with UAVs, first, dangerous situations must be determined, and the risk levels that will be caused by these dangers should be revealed. The proposed model is a basic model, and it should be revised depending on the different disciplines in which UAVs are used. Accordingly, in light of the measures to be taken against the risk levels to be identified and the lessons to be learned, the use of UAVs will become safer, more efficient and more common.

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