DOI: 10.1515/sspjce-2019-0003

Utilizing drone technology in the civil engineering

Matúš Tkáč, Peter Mésároš

Technical University of Košice, Slovakia
Civil Engineering Faculty, Institute of Construction Technology and Management
e-mail: matus.tkac@tuke.sk, peter.mesaros@tuke.sk

Abstract

An unmanned aerial vehicle (UAVs), also known as drone technology, is used for different types of application in the civil engineering. Drones as a tools that increase communication between construction participants, improves site safety, uses topographic measurements of large areas, with using principles of aerial photogrammetry is possible to create buildings aerial surveying, bridges, roads, highways, saves project time and costs, etc. The use of UAVs in the civil engineering can brings many benefits; creating real-time aerial images from the building objects, overviews reveal assets and challenges, as well as the broad lay of the land, operators can share the imaging with personnel on site, in headquarters and with sub-contractors, planners can meet virtually to discuss project timing, equipment needs and challenges presented by the terrain. The aim of this contribution is to create a general overview of the use of UAVs in the civil engineering. The contribution also contains types of UAVs used for construction purposes, their advantages and also disadvantages.

Key words: civil engineering, data capture, unmanned aerial vehicle, drone, aerial mapping

1 Introduction

Over the last decades, new digital technologies have appeared to enhance productivity, reduce overall time and cost of construction tasks. The introduction of drones to the construction industry is recent, although their use in other areas of industry (e.g., agriculture, public safety, military purposes, science and research, monitoring security, mining, etc.) has been frequent [1]. In the construction industry, aerial vehicles have been used for numerous purposes; such as, inspection of highways, bridges, roads, cell towers, high mast lighting, wind turbines, power transmission lines, building façade and roof, survey and mapping, construction monitoring, wetland/environmental, drainage and erosion, traffic monitoring, emergency services, etc. [1], [2]. UAVs provide invaluable help and cost savings with wide views of inaccessible and otherwise difficult and tough to navigate locations. UAVs indicate best access with the overhead perspective and 360° panoramas relay a real-time scenario. With this input, engineering teams can prioritize their approaches. Operators can share the imaging with personnel on site, in company and also with sub-contractors at the distance [3]. The data in terms of drone images from multiple locations and point clouds (from 3D scanning of construction site) can be used to construct a 3D model using the photogrammetry techniques. This so-called "drone model" can be compared to BIM model at various construction stages to monitor the construction progress. Beside construction scheduling and costing, this comparison can be expanded to include real-time recording, reporting, billing, verification and planning [4]. The construction industry is based on the human relationships between project stakeholders. Digital tools and processes cannot replace people, either as individuals or teams, but they are required to increase quality of work, reduce costs and safety risk, improve decisions, reduce time-consuming processes, etc. Drones present increasingly attractive opportunities for achieving these goals, e.g., a team of scientists has demonstrated that UAVs were able to build a rope bridge, assemble items to create a structure, or detect and catch an object in the air. On the present, UAVs offer a high level of automation that allows to reach previously inaccessible areas, while capturing a large amount of data very quickly. However, this is not their only use [5].

2 Types of drones used in the construction industry

The use of drones has been one of the most attractive construction trends in recent years. In the construction industry has seen an almost 240% increase in drone usage, higher than any other commercial sector. Drones offer such aviation benefits and capabilities that provide invaluable help in solving construction activities. Although there are a large number of drones on the market, commercial drones are commonly used in the construction industry [6]. Drones can be classified on a different basis, like drones for photography, drones for aerial mapping, drones for military purposes and surveillance, etc. However, the best classification of drones can be made on the basis of aerial platforms. Based on the type of aerial platform used, there are 4 major types of drones; fixed wing drones, multi rotor drones, single rotor drones and fixed wing hybrid VTOL drones [7].

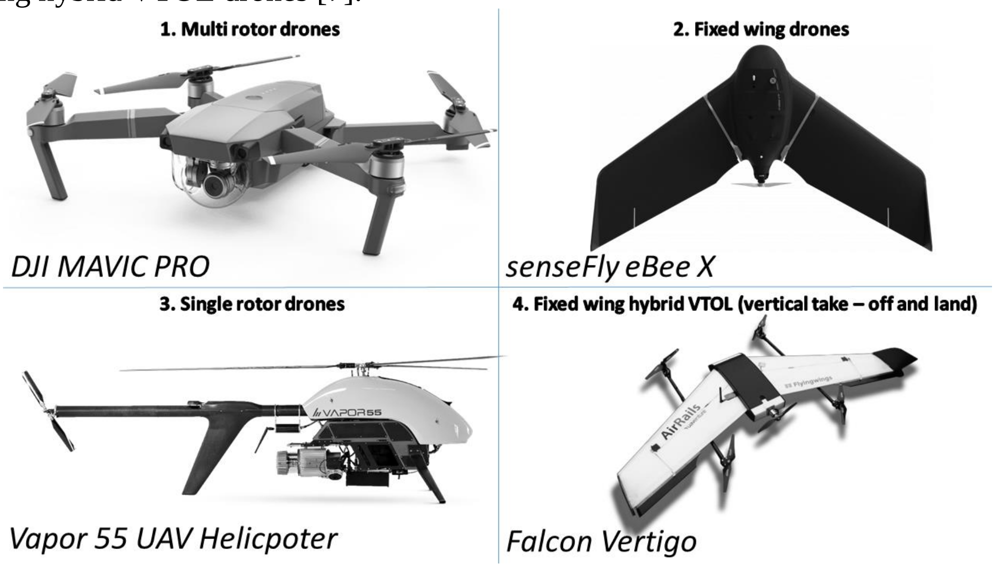

Figure 1: Different types of drones, source: [8], [9], [10], [11]

Multi-rotor drones are the most commonly used types of drones, which are used not only for fun, but also for professional aerial mapping. Common applications of multi rotors are aerial photography, video recording and aerial surveying. These types of drones can be classified according to the number of rotors, e.g., tricopters (3 rotors), quadcopters (4 rotors), hexacopters (6 rotors) and octocopters (8 rotors) [12]. The disadvantage of multi-rotor drones is their limited endurance and speed. Due to these limitations, these types of drones are not suitable for large scale aerial mapping, e.g. pipelines, roads, power lines, highways, etc. Despite the drone technology continues to improve, multi-rotor drones have to do a lot of effort to keep them in the air. Depending on the weight of the drone and camera, multirotor drones currently hold an average of 20-30 minutes or less in the air [13].

Fixed wing drones operate essentially on the same principle as passenger airplanes. These drones do not generate thrust by vertical rotors, but generate lift using fixed wings [12]. These types of drones need energy only to move forward and not to keep them in the air. For this reason, they are a much more efficient variant for topographic mapping of large areas and they are able to cover longer distances than multi-rotor drones. On the other hand, the main disadvantage of the fixed wing drones is the inability to stay in the air in one place, which prevents them from creating detailed aerial mapping, e.g. the as-built buildings. Another disadvantage of this type of drone is its take-off from the ground and landing on the ground. Depending on the size of the drone is necessary to have a runway or catapult launcher to get them into the air and on the other hand is necessary to have a runway to get them to the ground back safely [13]. The fixed wing design allows these drones to reach a higher altitude during flight, making them efficient tool for aerial mapping topography, but on the other hand they can only fly forward. For closer aerial work which requiring more detailed activities, e.g., detailed aerial mapping of buildings, the use of multi-rotor drones is a much better solution because they are easy to work with in the air and their rotor design allows them to hover stable in the air [6].

Multi-rotor drones generate vertical thrust using multiple rotors, but on the other hand a single helicopter drone uses only one rotor. The single helicopters drones can be powered by gasoline engines and thus last much longer in the air than multi-rotor drones. If it is necessary to fly with higher payload, e.g. with the LIDAR scanner, or if it is necessary for aerial mapping to combine a long endurance of the flight with forward flight, in this case a single helicopter drone is a good choice. The disadvantage of this type of drone is the increased complexity, cost, vibration, and they also require more mechanical maintenance due to their increased overall technical complexity [12].

Fixed wing unmanned aircraft is known to be more energy efficient than quadcopters and as a result can cover long distances much faster. But quad-shaped drones do not need that much space for take-off and landing. That is also why some manufacturers have decided to combine these characteristics and have developed unmanned aircraft that can take off vertically and then go into horizontal flight using wings. Their name is very similar to the automobile industry, and it, hybrid drones. The hybrid drone flies on a pre-scheduled flight route at a user-specified height and collects data through its color and multispectral sensors. Upon completion of its mission, the drone will land vertically back to the starting point [12].

3 Utilizing drone technology in the construction industry

The drone technology in the construction industry has a very wide range of applications. Drones can be applied in the construction industry in the following ways [14]:

Building Surveys

Almost every building survey of the building requires the visibility of the roof of the building in order to assess its technical conditions and to assess any defects or failures. In most cases, the ascent to the roof is complicated, which often requires the use of scaffolding, ladders or other auxiliary structures, which may ultimately pose a danger which are both time consuming and costly. Use of a small drone in these cases can save time, costs, reduce health and safety risks which are connected with the building surveying of the roof structure and with accessing to complex or hard to reach parts of the building's roof. [14].

Looking Fig. 2 it can be seen that for overall aerial mapping of the building it is necessary to create vertical (*left part of the figure*) and oblique (*right part of the figure*) aerial images. Vertical aerial photographic coverage of the roof is normally taken as a series of overlapping flight strips. The overall time for automatic mode was in this case 3 minutes and 100 aerial images were created. The oblique aerial images which were focused on the building's facade were created in the manual mode, it means, that this process is about the pilot's practical and personal experiences. In this mode, 950 aerial images were created in the distance from the building approximately 10 - 15 meters in three altitude levels. The comprehensive data collection time of aerial mapping was 2 hours and 1050 aerial images were created.

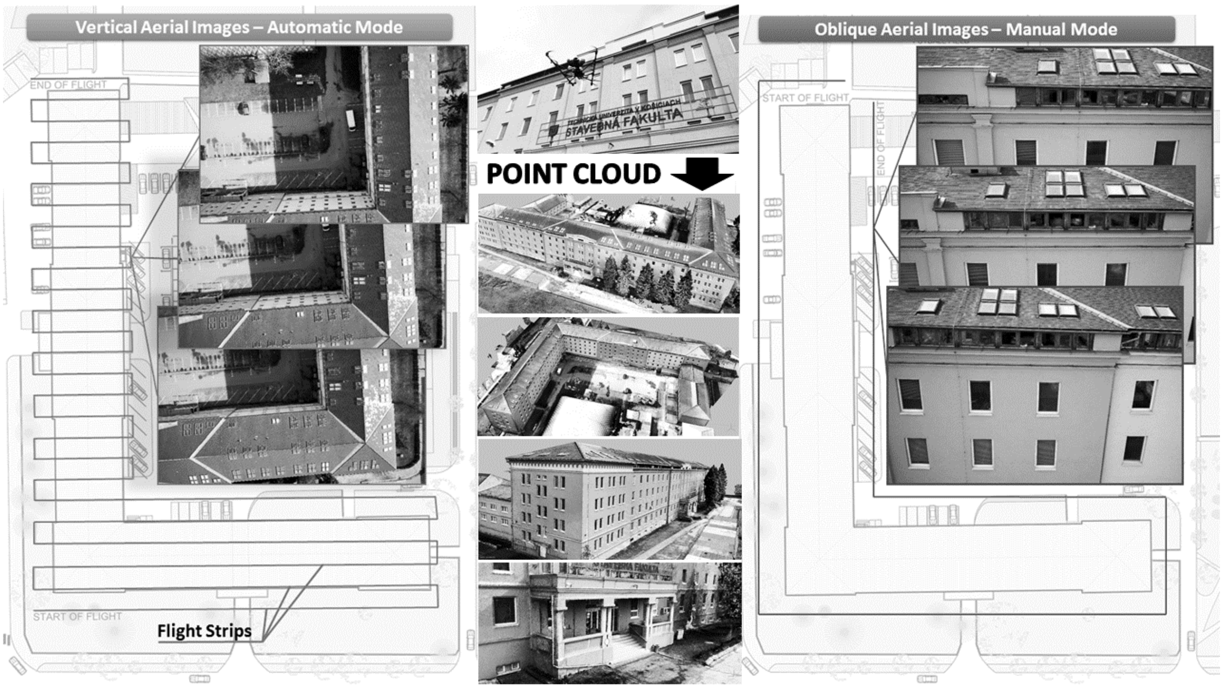

Figure 2: Example of technological process of creating vertical (left) and oblique (right) aerial images of building; source: authors

Topographic Mapping and Land Surveys

In the case of planning large-scale and complex construction projects, consultation of topographic maps is essential. Topographic maps may reveal construction design errors that are inappropriate for terrain. Although topographic maps are useful for construction projects, their production is often costly and time consuming. The use of drones is very effective in these cases. Due to its ability to capture large amounts of data in a relatively short time, it leads to significant cost savings as well as the project costs required for these activities. Drones, thanks to their capabilities, ensure project time, budget and accuracy. Furthermore, from the high quality aerial images produced by drones can be created 3D models of the surface (DSM-digital surface model) or of the terrain (DTM-digital terrain model) [6].

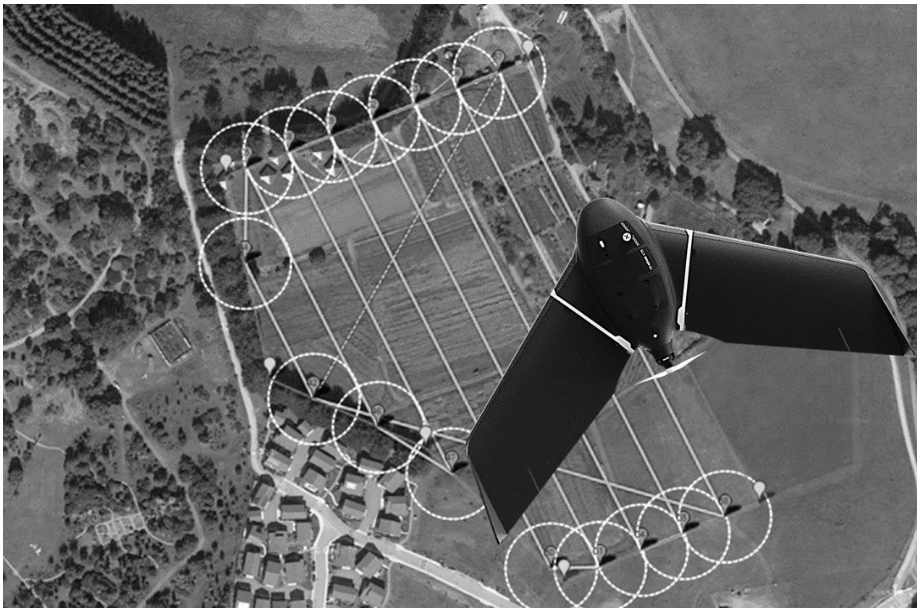

Fig. 3: Aerial mapping of the area of interest using a fixed wing drone; source: [15], [9]

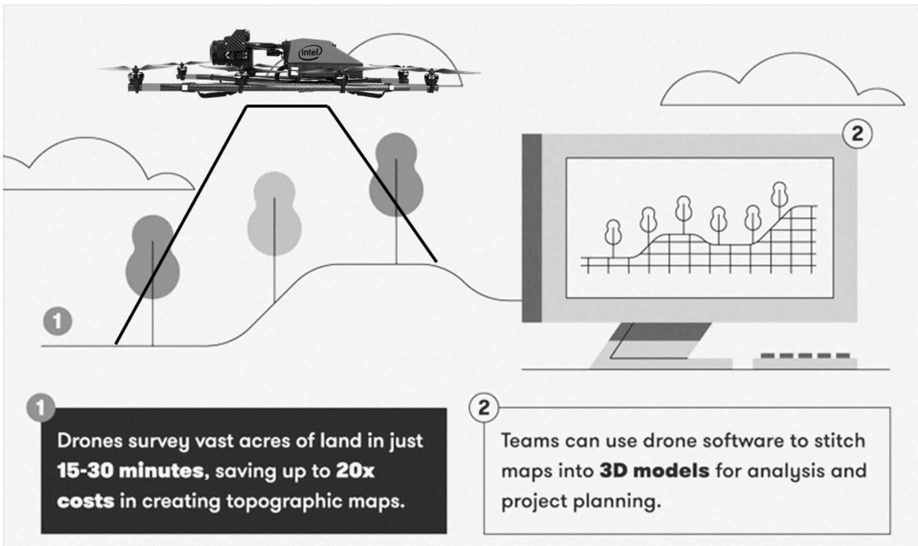

Figure 4: Topographic mapping and land surveys using a drone; source: [6]

Construction Site Inspections

For builders the data from drones can be collected frequently allowing easy integration into projects and tracking site progress precisely and with hardly any lag time. This allows construction companies to work more effectively in managing their time and resources while minimizing potential issues and delays [16].

Construction site inspection using drones can be a considerable tool for project teams. A pilot with experiences can use the drone to identify any construction or technical problems on the construction site and also using drones for inspection purposes is possible to ensure that the project goals will go according to plan. The use of drones can save thousands of euros in the case of rebuilds and plan changes. Using drones can be much safer as well because it eliminates spaces or areas on the construction site that could potentially be dangerous to assess the damage. With more advanced technology, it is possible also use a drone to fly around a construction site and check out how closely it resembles the construction plan or the model, drones can aid in the creation of detailed 3D models of new construction projects, drones can help to see what things look like on the roof of a skyscraper under construction, etc. [17]. Drone due to its ability to perform visual inspection of high risk areas on the construction site or on the new - exist building can save time, reduce health and safety risks. Aerial photographs can be documented from the safety of the site cabin and then sent to project team in HD quality very quickly and effectively. Site inspections can be undertaken more regularly and cover larger areas more efficiently [14]. There are four main benefits to using drones for construction site inspections: improved safety saves time, less labor-intensive and higher quality data [18].

Figure 5: Construction site inspection by a drone; source [6]

Equipment Tracking and Automating

Equipment tracking and automating is the problem of every project manager on the construction site. This is usually a problem with a large number of different tables and documents, which are often difficult and time-consuming to keep. Using the drone, the same project manager can immediately assess if the equipment is where it should be during the drone flight. It is also possible to quickly assess with a drone if a devices that have already completed its work is still on-site and with this solution is also possible to prevent expensive accidental extension charges [6].

Remote Monitoring and Progress Reports

Probably the biggest advantage of drones in the construction industry they can provide to clients is their visibility from the air, from a great height and from any location [6]. A constant drone flight on the construction site can represents a quick way to map the progress of a project, especially when the clients are not able to be physically present on a site [6], [14]. Thanks to multiple high-resolution aerial images and HD-quality videos, project developers can get a better overview of project progress at daily, weekly or monthly intervals [14]. According to [19] it's recommended to film only those areas of the new construction where the best progress is achieved, unless the client stipulates otherwise.

Integration of laser scanning and aerial photogrammetry

It is often difficult for a surveyor to gain access to a suitable laser scanning location from which would be possible to scan, e.g. roof construction. In this case the final point cloud can be incomplete. The drone technology in integration with the laser scanning can brings solution of this limitation. [14].

Looking Fig. 6 it can be seen the reference building where the technology of terrestrial laser scans and aerial photogrammetry using a drone were used. The measurement of this building was divided into two stages. In the case of terrestrial laser scanning (stage 1), the completely facade of the building was selected for digital surveying, and in the case of aerial photogrammetry (stage 2) the completely roof of the building was selected for digital surveying.

The total data collection time of the first stage was approximately 12 hours and together was created 48 scanner positions which were focused on the exterior part of the building. The total data collection time of the second stage was approximately 30 minutes (flight plan of the drone, aerial photographs in automatic mode, and aerial photographs in manual mode) which were focused on the roof construction of the building. In the second phase, a total of 302 aerial photographs were taken using a DJI MAVIC PRO quadcopter with a 12 Mpx digital camera, and the entire drone flight was performed with one battery.

The phase of data processing in this case consisted from three stages. The first stage was primary focused on creation of two point cloud from two technologies using the appropriate softwares. The second stage was about integration of two local coordinate systems from two point clouds into common coordinate system. This was very important step for the final connection of two point clouds. The last stage was about final connection of two point clouds based on the common coordinate system (Fig. 6). Data processing time for laser scanning was 3 hours and the Faro Scene and Autodesk Recap software were used. Data processing time for aerial photogrammetry was 31 hours and the "Agisoft Photoscan Professional" was used. The final point cloud includes now all space information about the building and this data can be used for either CAD or BIM modeling like a template for a new as-built project.

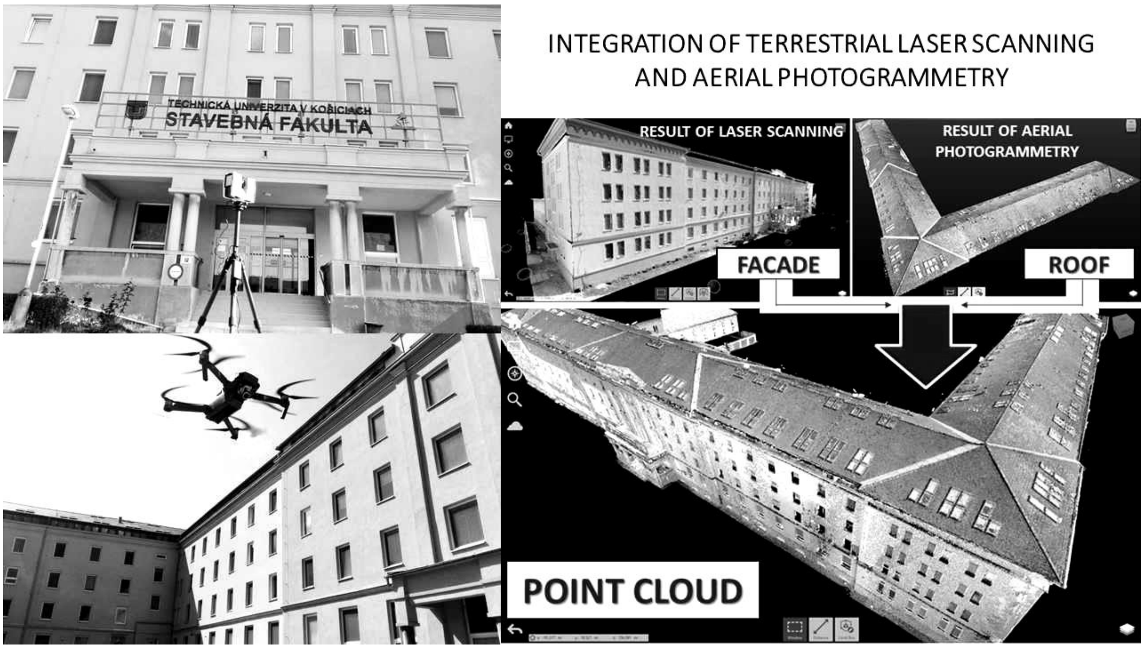

Figure 6: Connection of terrestrial laser scanning and aerial photogrammetry; source: author

Thermal Imaging recording

Similar to laser scanners, also drones can be used to create aerial thermal images from different parts of buildings which can be used to assess cold spots in buildings. This possibility can bring for engineers, surveyors and contractors necessary information about the building in the case when is essential to identify and rectify building defects, e.g. places where thermal bridges arise and the like [14]. Thermography allows determine thermal technical properties of building envelope and is used to detect hidden building defects. Thermography is able to find these failures with the necessary accuracy and, if evaluated correctly, is the basic step for effective design of the technical solution and consequently also for checking its realization. Combining thermography with drones allows detection of such construction defects that are not visible to the naked eye (Fig. 7) [14].

Thermal imaging of the certain part of the building can also help detect water infiltration, leaks, and areas with mold or rot before they cause serious damage. These cold, damp areas will appear as dark blue on the thermal imaging screen. From the inspector's standpoint, using the equipment to inspect rooftops, pinpoint leaks and detect heat loss make the process simpler, safer and faster and generally more efficient [20].

Figure 7: Example of drone thermal imaging; source [20]

Other uses of drones in the construction industry can be included security surveillance, personnel safety, health and safety inductions, maintenance inspections, promotional photography, live feed/ virtual walk around, site logistics, monitoring workers, etc. [6], [14], [19].

4 Conclusion

Drones are an important technological asset in the area of civil engineering. Their use in the construction industry will only increase in time because they can efficiently collect data of a high standard, greatly minimizes risk to the safety of a project team. In general, the construction industry is often careful in implementing new progressive technologies into production or in established workflows. The construction industry can be described as a fast-growing industry, and unmanned aerial vehicles technology was quickly adopted as a tool that saves costs, time and increases safety and control. Construction companies receive drones much faster than ever because of their innumerable benefits. Whether drones are used by construction companies for topographic terrain mapping, building surveys, land surveys, construction site inspections, remote monitoring, progress reports, thermal imaging recording or for integration with laser scanners, drones have proved as invaluable tool throughout the life cycle of a construction project. The drone capabilities enable them to save costs, time, risk and labor, which automatically lead engineers, contractors, investors or future customers to more confidence and certainty in working on a construction project.

Acknowledgements

The paper presents a partial research results of project APVV-17-0549 “Research of knowledge-based and virtual technologies for intelligent designing and realization of building projects with emphasis on economic efficiency and sustainability” and project VEGA 1/0828/17 “Research and application of knowledge-based systems for modelling cost and economic parameters in Building Information Modelling”.

References

[1] Motavwa, I., Kardakou, A. (2018). Unmanned Aerial Vehicles (UAVs) for Inspection in Construction and Building Industry. In: Proceedings of the 16th International Operation & Maintenance conference (OMAINTEC 2018), 18-20thNovember 2018, Cairo, Egypt.

[2] Cornwell, Ch., Knapp, C. (2017). Civil Engineering Applications of Drones, from https://static1.squarespace.com/static/5452a33de4b04219d5dae8f8/t/58fe4564bebafba91c2aca7f/1493058923629/NY2020_Civil+Engineering+Applications+of+Drones1.pdf

[3] Bourque, A. (2017, June). How drones are advancing civil engineering and surveying. Retrieved August 1, 2019, from https://www.computerworld.com/article/3199631/how-drones-are-advancing-civil-engineering-and-surveying.html

[4] Anwar, N., Izhar, A. M., Najam, A. F. (2018). Construction Monitoring and Reporting using Drones and Unmanned Aerial Vehicles (UAVs). In The Tenth International Conference on Construction in the 21st Century (CITC-10), July 2-4, 2018, At Colombo, Srilanka.

[5] A business approach for the use of drones in the Engineering & Construction industries. (2016). Retrieved August 1, 2019, from https://www.accenture.com/_acnmedia/pdf-24/accenture-drones-construction-service.pd

[6] Zitzman, L. (2018, October). Drones in Construction: How They’re Transforming the Industry. Retrieved August 2, 2019, from https://www.bigrentz.com/blog/drones-construction

[7] (2017, February). Types of Drones – Explore the Different Models of UAV’s. Retrieved August 2, 2019, from http://www.circuitstoday.com/types-of-drones

[8] Download Dji Mavic Pro transparent PNG. Retrieved August 2, 2019, from https://www.stickpng.com/img/electronics/dji-drones/dji-mavic-pro

[9] senseFly. eBee X Fixed-Wing Drone. Retrieved August 2, 2019, from https://www.sensefly.com/drone/ebee-x-fixed-wing-drone/

[10] Skyline UAV. Vapor 55 UAV Helicopter. Retrieved August 2, 2019, from http://www.skylineuav.com.au/fleet/vapor-55-uav-helicopter/

[11] UAS Vision. Affordable Ready-to-Fly Hybrid VTOL Drone. Retrieved August 2, 2019, from https://www.uasvision.com/2017/02/22/affordable-ready-to-fly-hybrid-vtol-drone/

[12] Drone Omega. Types of Drones. Retrieved August 2, 2019, from https://www.droneomega.com/types-of-drones/

[13] Chapman, A. (2016, June). Types of Drones: Multi-Rotor vs Fixed-Wing vs Single Rotor vs Hybrid VTOL. Retrieved August 3, 2019, from https://www.auav.com.au/articles/drone-types/

[14] Ayemba, D. (23, March). Utilizing drone technology in construction. Retrieved August 3, 2019, from https://constructionreviewonline.com/2018/03/drones-in-construction/

[15] Nixon, A. (2019, June). Best Drones For Agriculture 2019: The Ultimate Buyer’s Guide. Retrieved August 3, 2019, from https://bestdroneforthejob.com/drone-buying-guides/agriculture-drone-buyers-guide/

[16] Anra Technologies. Construction Site Inspections. Retrieved August 4, 2019, from http://www.anratechnologies.com/home/construction-site-inspections/

[17] Young, J. (2019, July). The Use of Drones in Construction Inspection and General Building. Retrieved August 4, 2019, from http://www.droneguru.net/the-use-of-drones-in-construction-inspection-and-general-building/

[18] Hook, J. (2016, November). Using Drones for Site Inspection. Retrieved August 4, 2019, from https://www.buildsoft.com.au/blog/using-drones-for-site-inspections

[19] Lawson, S. (2018, October). 7 Ways Drones Are Improving The Construction Industry. Retrieved August 4, 2019, from http://www.droneguru.net/7-ways-drones-are-improving-the-construction-industry/

[20] ICA. (2017, February). Drone Thermal Imaging: The Next Wave in UAV Inspection Services. Retrieved August 4, 2019, from https://icaschool.com/2017/02/13/drone-thermal-imaging-next-wave-uav-inspection-services/