Development strategies for unmanned aerial vehicles in the construction industry

Angela Mottaeva[1*]

[1]Financial University under the Government of the Russian Federation, 49, Leningradsky Prospekt, 125167, Moscow, Russian Federation

Abstract: The paper provides research on the use of modern drones or unmanned aerial vehicles (UAVs) for effective work in the fields of architectural design, construction management and monitoring. The authors examined the theoretical foundations and practical features of modern unmanned aerial vehicles (UAVs) or drones. Statistics on the structure of the global UAV market are presented. The detailed description of the primary applications of drones in the construction sector is provided. The main advantages of new technologies over traditional ones are noted. The paper pays attention to the issues of increasing safety at construction sites. The introduction of innovative technologies is necessary for the development of the construction industry. The use of such technologies will reduce task completion times, improve work quality, improve safety standards and reduce costs. At the same time, the authors noted some shortcomings of modern unmanned technologies. In the conclusion of the paper, insights are presented regarding the future possibilities for integrating unmanned aerial vehicles in construction projects.

1 Introduction

Unmanned aerial vehicles (UAVs) have various applications on construction sites. They provide a bird's eye view to monitor construction site personnel and also provide direct feedback on activities occurring on site. Given the high potential for using UAVs on construction sites, the construction industry has been slow to adopt them. Additionally, there is a need for further exploration to understand how UAVs can be used in various construction management activities. Issues related to the use of UAVs in the construction industry have not been sufficiently studied. There is a need for scientific research and evaluation of the performance of UAVs in the construction environment. This study was conducted to summarize the applications and challenges of their use in the construction industry, which will help identify several areas for improvement and future research.

This paper reviews the literature to identify the applications and challenges of using UAVs in the construction industry. Open statistical data were used as primary sources of information for the study. Scientific works of Russian and foreign researchers on the topic of using UAVs in the construction industry were also analyzed, such as: Noskov I.V. [1], Aicardi I. [2], Koubaa A. [3], Yang C.H. [4], Ellenberg A.[5], Ham Y. [6], Daponte P. [7],

* Corresponding author: doptaganka@yandex.ru

Cefalo R. [8], Kavelin A.S.[9,10], A.D. Anikaeva [11], A.S. Kudasova [12], Bakreen, S. [13], Nesterov E. [14], Niyazbekova S. [15]. The results obtained will help to understand and summarize recent research on the problems of using UAVs in the construction industry.

2 Methods

To achieve the goal of the study, general scientific and statistical methods of analysis and synthesis were used. The study's methodology is rooted in a comprehensive scientific approach to analyzing the inherent trends in the evolution of the construction industry amidst digital transformation, along with the challenges associated with the utilization of drones in construction

3 Results and Discussion

In recent years, the use of drones (Figure 1) or unmanned aerial vehicles (UAVs) in design, construction and other construction-related fields has been increasingly gaining momentum. Unmanned aerial vehicles (UAVs), or drones, are uncrewed aircraft that are controlled:

- ✓ remotely;
- ✓ using autonomous software installed on board the UAV;
- ✓ using GPS navigation.

Currently, UAVs are actively used in various industries:

- ✓ in architecture and urban planning;
- ✓ in urban management;
- ✓ in cartography and cadastre;
- ✓ in photography and cinematography;
- ✓ in agriculture.

Technological advances in the design and navigation of lightweight and autonomous UAVs and drones have led to their more practical and cost-effective operation in the fields of architectural design, construction management and monitoring. This trend is observed in all developed countries of the world. Unfortunately, the rate of adoption of innovative technologies in the construction industry is much lower than in some other industries. This is due to a number of restrictions and barriers, as well as the dynamic nature of construction sites. [1].

Fig. 1. UAV (Propeller PPK, DJI Phantom 4 RTK drone) https://www.dji.com/ru/phantom-4-pro

Construction is one of the world's largest industries. Leading companies in the industry are implementing innovative technologies within the construction sector to streamline expenses and enhance potential profitability [2].

An innovation that has gained significant traction in recent years is the extensive adoption of drones in the construction field. These are flying robots that can be remotely

controlled or fly autonomously using software-controlled flight plans built into a GPS system.

Over the past 10 years, there has been an explosion of innovation in the field of unmanned aerial vehicles [3]. Figure 2 and Figure 3 show the structure of the global UAV market. As depicted in the diagrams, there is a clear need in Russia to enhance research and development efforts and proactively facilitate the establishment of drone manufacturing capabilities. This should become a strategic goal of the national industry within the framework of import substitution projects.

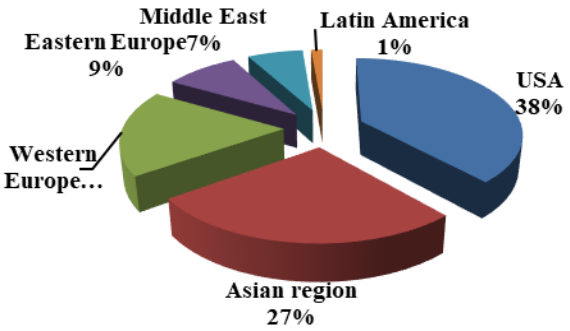

Fig.2 Volume of the global UAV R&D market

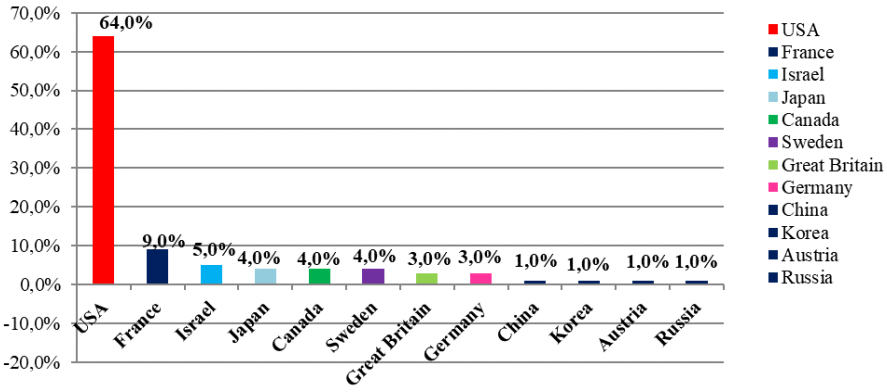

Fig.3 World market for UAV production

Let's look at the criteria by which the Russian and American drone technology markets are assessed.

1. Scale of investment.
2. Areas of implementation.
3. Difficulties in legal regulation.
4. Willingness to accept new technologies.

Thus, in the United States, the *Federal Aviation Administration* has introduced mandatory registration of all UAVs before flight in order to obtain a certificate that allows them to legally operate unmanned aerial vehicles in construction. Other countries have similar policies and are developing new legislation to regulate the licensing, training, activities and responsibilities of drone operators. The *EU Civil Aviation Authorities (CAAs)*

issue flight authorization on a case-by-case basis. Some EU countries have their own national rules. In Russia, the *Air Code* provides for mandatory registration and obtaining a permit.

The scale of the construction industry facilitates the effective use of drones.

What tasks can UAVs perform?

1. Topographic survey and cartography.
2. Create aerial photographs and 3D urban planning models
3. Increased safety on construction sites
4. Roof inspection and building maintenance.
5. Security surveillance.
6. Advertising and marketing.

Topographic survey. It is an integral part of all construction projects. Land management involves taking measurements of a specific plot of land before the start of construction [4].

One type of equipment used for this purpose is unmanned aerial vehicles (UAVs). Drones provide a more complete picture of the work being done. Using drones, topographic surveying has the following advantages:

• reduction of time and costs for field work [5];

• absence of logistics failures;

• more accurate measurements. High-definition photography allows developers to create 3D models of sites or buildings. The results obtained are significantly superior to traditional ones [6];

• the ability to compile maps of hard-to-reach areas. Unmanned surveys eliminate the need for surveyors to be physically present in unfamiliar or inaccessible areas.

For example, Antonia Bava Landscape Architects, a company from San Francisco (Fig. 4), uses drones for planning work for the construction of residential projects and even to develop master plans for territories. Skycatch is an American service created with Autodesk, which immediately received more than $20 million in investments, offering the creation of 3D models and terrain maps from photographs from drones and quick calculation of distances, areas, volumes (Fig. 5). During the construction of the Belo Monte dam, drones from the Bird Eve company are used (Fig. 6). With their help, scientists study the environmental impact on Brazilian tropical forests and monitor possible erosion and drought. Drone flights are daily, collecting several gigabytes of data per hour-long flight for environmental engineers.

Fig.4 Drones utilized for project planning in residential construction https://dronomania.ru/wp-content/uploads.png

Fig.5 Skycatch drone
https://www1.djicdn.com/cms_uploads/ckeditor/pictures/1273/content_Drone_devices.png

Fig.6 Drone for monitoring the ecological state of tropical forests. https://pixy.org/src2/669/6691705.jpg

Urban planning. Developments in drone technology over the past five years have led to a number of opportunities for the use of aircraft in urban planning. The technology makes it possible to study the existing social and environmental conditions of objects [7]. It becomes possible to accurately record traffic and changing urban infrastructure, topographical, hydrological changes and environmental degradation.

Foster + Partners, together with Be Tomorrow UK, are inventing robotic drones to identify minimal deviations from the project during implementation. Now Foster is teaching drones not to interfere with technological processes at the site (Fig. 7).

Fig.7 Robotic drones.
https://i.pinimg.com/originals/2e/e9/c8/2ee9c8a6741b96f931908964b7efc62a.jpg

Worker Bee is a drone that can paint houses and ships, spray chemicals, or clean windows. The idea comes from Florida-based company Apellix. It is now safe to paint or wash the skyscraper. (Fig. 8).

Fig.8 Worker Bee drone
https://ic.pics.livejournal.com/lakhtacenter/34674528/693272/693272_original.jpg

Improving safety on construction sites. The construction industry is one of the most dangerous fields to work in. According to a study by the US Occupational Safety and Health Administration, there were 4,674 worker fatalities reported in 2020, 20.7% of which were construction-related [8]. Most of these tragedies occurred due to falls. Construction companies must do everything in their power to reduce workplace injuries, and drones can help with this. Workers are exposed to accidents that lead to financial losses and disability. UAVs can improve construction methods and ease the work of safety inspectors, instantly notify operators of accidents and help locate incidents. Visual data collected by UAVs can improve site safety monitoring by improving the visualization of work situations.

Komatsu has combined drones with the SmartConstruction concept. Drones from the Skycatch company (USA) fly over a construction site, 'watch' and send information about what they see to the special equipment with artificial intelligence. Further, drones monitor the operation of smart excavators and bulldozers in real time (Fig.9).

Fig.9 Smart drones
https://dronedj.com/wp-content/uploads/sites/2/2018/03/product-shots-explore1-midair.jpg

Roof inspection and building maintenance. Recently, more and more construction companies are using unmanned inspection technology to inspect buildings and other structures. Drones provide the ability for companies and individuals to safely and quickly inspect roofs, including hard-to-reach areas of complex structures.

This sets the innovative method apart from expensive, risky, capital-intensive and labor-intensive traditional control methods.

It is possible to purchase drones and associated software, hire professional operators to conduct inspections, process data and provide them with actionable information. This cost-saving approach is ideal for single-use scenarios, such as by prospective home buyers. However, for organizations planning to conduct regular inspections, construction and repair, it is preferable to have their own equipment and appropriate personnel with the skills to work with it [9, 10].

Here are some of the problems associated with traditional inspections:

• presence of heavy and expensive equipment;
• need for highly qualified personnel;
• high labor intensity and danger of work.

Drones are safer, faster and more accurate at detecting damage, leaks, cracks and other signs of structural failure. The technology helps reduce inspection costs, reduce time and improve safety. For example, the traditional three-week review process is reduced to just a few hours.

In addition to structural and surface analysis of the roof, unmanned inspection is also possible when checking solar panels for defects. For example, searching for mechanical damage, panel overheating using thermal imaging, detecting excessive contamination, etc. [11].

Thermal imaging is a priority in the development of unmanned aerial vehicles, as it allows the inspection of pipelines, solar panels, electrical networks and roofs for leaks, overheating, failure and insulation damage.

Using traditional means, identifying insulation defects is a labor-intensive and physically exhausting task. However, drones greatly simplify this procedure and require only a few hours at a low cost [12]. A UAV installed with thermographic cameras can capture heat flow, allowing for mapping of roof insulation or pipe insulation issues, and also allows access to the interior of construction projects, which is not possible with a helicopter due to size limitations and limited ability to access outdoor areas.

Another application of UAVs is to conduct roof assessments. Some contractors use UAVs to assess roofs because some roofs are difficult to walk on and can be easily damaged.

The DJI FlyCart 30 cargo drone is the latest development of the Italian startup FlyingBasket, capable of moving cargo over a distance of up to 2.5 km with a full load of 100 kg. These characteristics make it suitable for a wide range of applications, including industrial logistics, forestry transportation, power line construction or solar panel installation (Fig. 10).

Fig.10 Cargo drone
https://infocity.tech/wp-content/uploads/2024/01/DJI-FlyCart-30.png

TraceAir, a Moscow-based company, offers a service that utilizes a quadcopter to assess the work completed and compare it with the projected estimates. It rises into the air above the construction site and begins to fly over the area. It is controlled from the ground by a

pilot. After a couple of hours, the engineer will be able to run a 3D model of the buildings under construction on a computer to check the progress of work, or during the zero cycle, calculate how much earth has been removed from the pit (Fig. 11).

Fig.11 Scanning of the construction site https://id.foursquare.com/v/one-timedevelopment-company/5a5ccf3f42d8c2565f680676

Advertising and marketing. High-resolution aerial photography is useful for producing quality marketing materials. Multi-angle and panoramic photographs of construction projects are required to effectively showcase the completed building and the construction progress to potential buyers.

Security surveillance. Research shows that more than $350 million worth of construction equipment is stolen from jobsites each year, with less than 30% of it ever recovered. The drone operator can detect and prevent various types of damage at any time. A surveillance camera equipped with a facial recognition program also detects the presence of strangers at the site. [1,12, 13,15]. Despite their appeal and clear benefits, drones come with certain drawbacks that need to be considered.

In the field of architecture, engineering and construction, UAV has become a new research topic for 3D mapping. Three-dimensional mapping allows you to monitor the progress of work on the site, perform geodetic and measuring tasks, and carry out quality control. For example, UAVs can be used to create interactive maps of buildings and sites by conducting site surveys and constructing 3D models of those locations. For large area mapping tasks such as excavations, UAVs are positioned as reliable and efficient devices. Contractors monitor their construction activities using UAVs because live broadcast of the work progress reveals potential hazards, enabling prompt decision-making [1,9, 10,12-15].

Aerial photography of the interior and exterior of construction sites is currently the most common application of UAVs. The capabilities of UAV equipment have expanded significantly, providing improved, high-resolution images from multiple angles. As a rule, permanent surveillance camera systems are installed on construction sites. As construction sites are cluttered with materials, it becomes impossible to fully view the camera's fixed range. In such situations, the UAV can maneuver around any obstacles and cover all the necessary locations, providing aerial photographs from various angles and heights [11,12]. Researchers consider it a low-cost aerial photography tool for construction inspection, especially for dangerous or impossible locations such as roofs and building facades.

Once a site is built, drones can detect defects. The emergency technical condition of a building is revealed after the collapse of its individual elements, which poses a danger to people. For example, when examining multilayer wall structures with a brick facing layer in frame buildings, it is problematic to identify hidden defects and damage. Aerial photography after data processing provides complete information about the nature of damage to the object in the shortest possible time and can be used as an express method for preliminary assessment of the technical condition of the facade (Fig. 12).

Fig.12 Technical condition of the building facade
https://www.geoscan.ru/ru/blog/vmesto-geodezista-i-okhrannika-kak-bpla-ispolzuyutsya-v-stroitelstve

Initially, UAVs were used in the military industry. However, the current situation has changed, and an increasing number of researchers are studying the use of UAVs on construction sites. Nowadays, interest in civil and commercial applications is driven by a wide range of applications, as well as labor, time and cost savings and increased productivity. UAVs, replacing traditionally used techniques, can provide information about the actual conditions of a construction site with a low error rate. The use of UAVs in the construction industry is a relatively new concept that is changing the way business is done [1,5,10].

Although drones are unmanned aerial vehicles, they still require human intervention, and careless or unprofessional operation can result in collisions resulting in injury and property damage.

4 Conclusions

Based on the study, it was revealed that UAVs have not yet received widespread use in the Russian construction industry. Drones are innovative technologies that can be very useful in various areas in the construction industry. Thus, we can state the following:

1. The use of such innovations in construction is an ideal environment for the development of the scientific and technological revolution. The introduction of this innovation will contribute to a technological breakthrough that ensures the priority of our state and the development strategy of unmanned aerial vehicles in the construction industry.
2. Foreign experience in the use of drones for the design and construction of buildings and structures shows that a fully automated system can reduce costs and effort for monitoring and reporting procedures during the construction of objects. In addition, monitoring construction sites using unmanned aerial vehicles (UAVs) makes it possible to identify cases of violations for prompt action and analysis of the results.
3. The use of such equipment on a construction site will help increase the speed and safety of work performed, productivity and quality of work. The anticipated advantage from replacing traditional lifts and cranes is estimated to be around 20%.

It is necessary to adopt a program to intensify the use of UAVs in geological and engineering exploration, monitoring of extended objects, and delivery of goods to construction sites.

In our country, which has a modern, developed aviation and construction industry, it is necessary to adapt the experience of using UAVs to the construction industry. The use of drones in the construction industry has great potential and many prospects for solving current problems in optimizing the requirements and rules for their use.

Thus, the use of drone technologies in the world and in Russia is becoming the inevitable future of the construction industry. And the sooner the implementation begins, the higher the competitive advantage will be.

References

1. Noskov I.V., Noskov K.I., Tinenskaia S.V., Ananev S.A. (2020). The Eurasian Scientific Journal, [online] **5(12).** Available at: https://esj.today/PDF/37SAVN520.pdf
2. Aicardi I., Chiabrando F., Grasso N., Lingua A.M., Noardo F., Spano A. UAV // International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences. 2016. No. **41**. pp. 835-842.
3. Koubaa A. Robot Operating System (ROS): The Complete Reference. Luxembourg: Springer, 2019, 82 p.
4. Yang C.H., Wen M. C., Chen Y. C., Kang S. C. An Optimized Unmanned Aerial System for Bridge Inspection // Proceedings of the 32nd ISARC, Oulu, Finland. 2015. pp. 625-630.
5. Ellenberg A., Branco L., Krick A., Bartoli I., Kontsos A. // Journal of Infrastructure Systems. 2014. No. **21(3).** pp. 21-27.
6. Ham Y., Han K.K., Lin J.J., Golparvar-Fard M. // Visualization in Engineering. 2016. No. **1**. pp. 289-296.
7. Daponte P., De Vito L., Mazzilli G., Picariello F., Rapuano S. // Measurement. 2017. No. **98**. pp. 192-198.
8. Cefalo R., Zielinski J.B., Barbarella M. New Advanced GNSS and 3D Spatial Techniques: Applications to Civil and Environmental Engineering, Geophysics, Architecture, Archeology and Cultural Heritage, Luxembourg: Springer, 2017, p. 19.
9. Kavelin A.S., Tyutina A.D., Nuriev V.E., Kolotienko M.A. // Engineering Journal of Don, 2019, No. **6.**
10. Kavelin A.S., Tyutina A.D., Nuriev V.E. // Engineering Journal of Don, 2019, No. **5**.
11. A. Anikaeva, D. Martyushev. Perm Journal of Petroleum and Mining Engineering. 2020. Vol. **20,** No. 4. P.344-355. DOI: 10.15593/2712-8008/2020.4.4
12. A.S. Kudasova, A.D. Tyutina, E.V. Sokolnikova. // Engineering Journal of Don, No. **8** (2021), ivdon.ru/ru/magazine/archive/n8y2021/7125
13. Bakreen, S., et al // Transportation Research Procedia 2022, **63**, pp. 1431–1443
14. Nesterov E., et al. // Transportation Research Procedia **63** (2022) 1404–1409, DOI: 10.1016/j.trpro.2022.06.151
15. Niyazbekova, S.,et al., // E3S Web of Conferences, 2023, **371**, 04039 https://doi.org/10.1051/e3sconf/202337104039