Report on Strategic Technology Roadmap for Drone Skills

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Project Title:

DRONE4BUILD

Elevating the knowledge of construction professionals on the use of drones in construction

CONTENTS

Summary

This strategic report examines the skills requirements for the effective use of drones in the construction sector, with a particular focus on building renovation and retrofitting activities. It provides a comprehensive analysis of existing and emerging skill gaps and upskilling needs, driven by rapid technological advancements, increasing digitalization, and evolving industry and regulatory demands. In this context, the report identifies the most relevant competencies related to drone operation, data acquisition and processing, and regulatory and safety compliance, emphasizing the growing importance of digital literacy within the construction workforce.

In addition to skills analysis, the report offers a foundational overview of drone technology, including an explanation of core technological principles, the historical evolution of drones, and an overview of their main fields of application, with particular emphasis on construction and building renovation. This will help create a shared understanding of drone capabilities and limitations and provide context for linking technological developments to workforce skill requirements.

The report was created within the framework of the Drone4Build project and adopts an interconnected training perspective that addresses the needs of both trainees and trainers. Its primary objective is to shed light on skills shortages in the construction sector, particularly regarding advanced digital technologies and drone-enabled solutions for renovation activities. The report contributes to updating the training needs of construction professionals in digital skills related to emerging technologies, while also providing space for workers to reflect on their familiarity with drones and to identify potential gaps in new-generation digital competencies.

To ensure a participatory and evidence-based approach, the report employs a mixed-methods approach, combining literature review, semi-structured interviews with industry stakeholders, and participatory workshops with construction professionals and VET educators across all partner countries. [1], [2] These workshops are designed to capture and assess the knowledge and skills of construction workers, trainers, and educators in the field of digital technologies for the construction industry, wit

h a specific focus on drone applications.

This report is the first outcome of Work package No.2 - Digital Skills Ecosystem for Drones, and it aims to set the framework for enabling digital literacy in the use of drones in construction. Through structured analysis of drone technology, construction applications, and skills requirements, this report identifies not only what workers need to know and do, but also how those competencies map to internationally recognised frameworks. It acts as an introduction of the second key outcome of Work Package No.2 which is the development of a comprehensive competency map covering drone-related technical, operational, regulatory, and safety skills for trainees.

Construction professionals require competencies spanning technical operations, advanced data processing and analysis, regulatory knowledge, and integration capabilities, but current VET systems inadequately address these needs, particularly in data processing, workflow integration, and business case development [3].

This competency framework will serve as a reference guide for VET centres, training providers, and industry stakeholders, and acts as a validation tool for the development of the Drone4Build curriculum in WP3, ensuring that training modules reflect real-world industry needs and support the sustainable adoption of drone technologies in the construction sector.

The outcomes will explicitly align to:

- European Digital Competence Framework (DigComp 2.2), addressing 5 competence areas and 21 digital competences with 8 proficiency levels.
- European Skills, Competences, Qualifications and Occupations (ESCO), enabling EU-wide recognition and occupational standardization.
- European Qualifications Framework (EQF) Levels 3-5, ensuring qualification compatibility across EU member states.
- EASA Regulatory Framework, ensuring compliance with current EU drone operation categories and certifications (Open, Specific, Certified).

1. Introduction

Unmanned Aerial Vehicles (UAVs), commonly known as drones, are aircraft systems that operate without an onboard human pilot and are either remotely piloted or capable of autonomous flight. Over the past two decades, drones have evolved from niche military platforms into widely adopted civil, commercial, and governmental tools. This evolution has been driven by rapid advances in electronics, embedded computing, communications, artificial intelligence, and regulatory frameworks, particularly within Europe.

Construction represents one of Europe's largest employment sectors, yet faces persistent challenges in workforce upskilling, safety, quality assurance, and environmental sustainability. Recent literature emphasizes that digital transformation in construction is not optional but essential for competitiveness and compliance with EU Green Deal objectives [4], [5].

Therefore, this document provides a technical overview of the technological development of drones and a structured analysis of their main application fields, particularly in construction.

Research methodology

2. Research methodology

In order to prepare the Strategic Report which outlines skills requirements for drones in the construction sector as one of the main results of Work package No.2 of DRONE4BUILD, a robust research methodology was used, including analysis of skill gaps, upskilling needs, and defining core competencies.

2.1. Research Objectives

This report aims to:

- Assess current and future skills required in drone use for construction.
- Identify skill gaps between industry needs and workforce capability.
- Propose upskilling pathways and competency frameworks for drone operations, data analysis, and compliance.

2.2. Mixed-Methods Research Design

For the preparation of the report, a mixed-methods approach, combining quantitative and qualitative methods to collect rich, reliable data was used.

2.3. Literature and Policy Review

This report includes a comprehensive review of:

- Technical literature on drone technologies in construction.
- European regulatory landscape and frameworks.
- Industry and occupational standards for drone operations.
- Training frameworks already in existence for drone operation and data science.

This will provide context for skill needs based on technological advancement and compliance requirements.

2.4. Quantitative Methods

In the frame of the quantitative methods a comprehensive Industry data analysis per project country will be conducted (example of the questionnaire sheet given as Annex 1), reviewing the following:

- employment data, certification statistics, job specifications related to drone-specific roles in construction.

2.5. Qualitative Methods

In order to identify which skills are required for integrating drones into the construction workflow, semi-structured interviews will be conducted (example given as Annex 2):

- Profile of stakeholders: drone users and service providers, construction/renovation experts, VET educators.
- Goal: Explore perceptions of technological trends, training challenges and skill gaps, regulatory awareness and compliance.

For the purpose of validation of the content of the strategic report on drone skills, interactive workshops will be organised:

- Format: interactive workshops.
- Profile of participants: drone specialists, construction professionals, VET providers.
- Goal: highlight real-world challenges and tacit skill requirements.

2.6. Competency Framework Development

The project will produce a clear competency structure by taking the following steps:

2.6.1. Mapping Technologies to Skills

Identify how technological capabilities (e.g., photogrammetry, BVLOS, automation) translate into required skills:

Technology Aspect	Required Skill Example
Flight planning & BVLOS	Advanced drone piloting, risk assessment
Sensor data collection	Sensor calibration, data logging
Photogrammetry	GIS & point-cloud processing
AI analytics	Machine learning & image interpretation
Regulatory compliance	Knowledge of U-space, aviation law

2.6.2. Define Skills Categories

- Operational Skills
  e.g. Drone piloting, safety checks, emergency procedures.
- Technical Skills
  e.g. Data processing, software tools (e.g., Pix4D, DroneDeploy), analytics.
- Regulatory, Safety & Compliance Skills
  e.g. EU law, site-specific authorizations, data privacy.
- Soft Skills
  e.g. Project planning, team coordination, documentation.

2.6.3. Gap Analysis

Compare current workforce capability against required competencies by using the following methodological steps:

- Benchmark against industry standards.
- Use ISO/IEC or national qualifications as reference points.
- Quantify Gap Severity (percent of workforce lacking specific skills, industry impact ratings).
- Upskilling Needs Assessment

2.6.4. Based on gap analysis, identify:

- Training Needs
  - Short-term (certifications, modular courses)
  - Medium-term (internships, workshops)
  - Long-term (higher education tracks, micro-credentials)
- Learning Pathways

Design structured learning pathways for different roles with differentiated proficiencies.

2.6.5. Validation and Stakeholder Review

Before finalizing the report:

- Expert review.
- Industry, academic, and policy representatives provide feedback.
- Proof of concept and pilot testing.
- Validate competency framework.

Tools & Frameworks to be used:

- SWOT Analysis for skill ecosystem.
- Competency Matrices with small groups through simulated or real training exercises.
- Bloom's Taxonomy (to define proficiency levels).

Technologies for Drones

3. Literature review: Technologies for Drones

The current scientific literature has limited visibility into industrial research and development, as well as aspects of manufacturing, production capacity, and supply chains which are critical technological elements for the adoption of drones. The following literature review is based on comprehensive review papers to provide a broader overview of the current drone research.

3.1. Key terms and definitions:

The following key definitions are used in the presented report:

- Drones - following the Drone Strategy 2.0 (EC, 2022a), this is the term to describe unmanned aircraft systems (UAS), meaning an unmanned aircraft vehicle (UAV) [6] and the equipment to control it remotely. Unmanned aircraft encompasses a wide range of vehicles, in terms of size, reach, and application domain. It is an aircraft without a human pilot on board that is remotely or autonomously controlled.
- Innovative Air Mobility (IAM) [7] refers to operations with novel aviation systems. Innovative Air Mobility covers a wide range of novel aircraft technologies and concepts, which include electric vertical take-off and landing (eVTOL) capability, specific propulsion features such as distributed propulsion or tiltrotor, and can be either manned or unmanned, autonomously or remotely controlled. Urban Air Mobility (UAM) is a part of Innovative Air Mobility3, aiming to enable on-demand mobility, reduce congestion and expand transport options in congested urban areas.
- Unmanned Aircraft System Traffic Management (UTM) is a set of services designed for the automated management of the airspace, ensuring safe and secure unmanned aircraft flights in both controlled and uncontrolled airspace. Controlled airspace refers to the airspace that is under the authority of air traffic control [8].
- The international regulatory bodies that work together in the context of JARUS (Joint Authorities for Rulemaking on Unmanned Systems) initiative.
- European authority for aviation safety - EASA (European Aviation Safety Agency)

- Single European Sky Air Traffic Management (SESAR) Joint Research - a set of services and procedures to help drones access airspace safely and efficiently.
- Vertical take-off and landing (VTOL) aircraft - refers to an aircraft capable to take off and land vertically, without requiring a runway, however after vertical ascent they can also transition to horizontal flight. European Union Aviation Safety Association (EASA) adds that unlike helicopters, VTOL aircrafts are using more than two propulsion units, referred to as distributed propulsion. Electric VTOL aircraft uses electric power to hover, take off, and land vertically.

3.2. Technical Overview and Classification

The following definitions are used in the presented report:

An Unmanned Aerial System (UAS), commonly referred to as a "drone," comprises an unmanned aerial vehicle (UAV), a ground control station, and associated systems that enable remote or autonomous flight operations. Unlike traditional crewed aviation, UAS operations require fundamentally different skill sets, certification pathways, and regulatory compliance frameworks.

Formal Definition by EASA:

UAS refers to a drone, its system, and all the other equipment used to control and operate it, such as the command unit, the possible catapult to launch it, and others.

UAV means any aircraft operating or designed to operate autonomously or to be piloted remotely without a pilot on board. [6]

3.3. Drone technology

Unmanned Aerial Vehicles (UAV), also commonly referred to as drones, are air vehicles together with their associated equipment that do not carry a human operator but instead are remotely piloted or capable of autonomous flight. Drones are increasingly considered for commercial and government civilian applications, ranging from firefighting to agriculture through the generation of climate data, border surveillance, and so on. They can perform air operations that manned aircrafts struggle with, and their use brings significant economic savings and environmental benefits whilst reducing the risk to human life. They have already made the leap to leisure market, reaching millions of sales. Evolution in technology, regulations and society acceptance should favour an accelerated deployment of drones in professional applications. According to a 2017 study done by the Teal Group [7], the world civil drone production is forecast to make up $73.5 billion in the next decade, soaring from $2.8 billion worldwide in 2017 to $11.8 billion in 2026, a 15.5 % compound annual growth rate in constant dollars.

Drone-based service and product innovation is curtailed by the growing dependence on poorly interoperable proprietary technologies as well as by the risks posed to people on the ground, to other vehicles and to property (e.g. critical infrastructure). In addition, the absence of a clear regulatory framework at EU level does not currently allow the creation of a truly European market for drone services and aircraft, which limits the potential for jobs and growth creation in this new sector of the economy.

For the regulatory aspect, because a professional drone is not an airplane, it is necessary to define an appropriate regulatory framework. For this purpose, the international regulatory bodies work together in the context of JARUS (Joint Authorities for Rulemaking on Unmanned Systems) initiative [8]. In addition to national authorities, Europe participates in this work through EASA (European Aviation Safety Agency) [6].

Regarding the innovation aspect, the Single European Sky Air Traffic Management (SESAR) Joint Research Undertaking is developing a set of services and procedures to help drones access airspace safely and efficiently. In order to realize this potential, SESAR is developing the concept of U-space [9]. U-space is a set of new services and specific procedures designed to support safe, efficient and secure access to airspace for large numbers of drones. SESAR's vision is that of a harmonized, as opposed to a fragmented, single market for drones. They identify four phases of development of the U-space services [4] :

- U1 - foundation (e-registration, e-identification and pre-tactical geofencing),
- U2 - initial (tactical geofencing, flight planning management, weather information, tracking, monitoring, drone aeronautical information management, procedural interface with air traffic control, emergency management and strategic deconfliction),

- U3 - advanced (dynamic geofencing, collaborative interface with air traffic control, tactical deconfliction and dynamic capacity management) and
- U4 - full services (which are yet to be defined).

This issue was identified to have high impact on European innovation by the "European Air Traffic Management (ATM) Master plan: Roadmap for the safe integration of drones into all classes of airspace" [10] and the "European Drones Outlook Study: Unlocking the value for Europe" [11], both published by SESAR JU. These reports demand R&D investments and incentives for the convergence of shared technologies and markets as a remedy. While "Unmanned Aircraft System Traffic Management" refers to the operational concept under research, U-space airspace management is the European framework aimed at its practical implementation. This includes the development of the regulatory framework and an execution roadmap with clearly defined steps and milestones. U-space encompasses the digital infrastructure, services and automation of functions designed to support safe, secure and efficient access to urban airspace and safe integration with other air traffic, for a large number of unmanned aircraft systems (EC, 2021a).

3.4. The Evolution of Drone Technology

In a relatively short period, drones have transitioned from recreational toys sold in most bigger supermarkets to becoming disruptive forces across a multitude of industries. By now, technological advancements coupled with the recognition of their potential in commercial applications, have propelled drones into the mainstream.

3.4.1. Early Days

The very first uncrewed vehicles were developed during the First World War. These radio-controlled aircraft were used as targets for training purposes. Drones then gained popularity as hobby gadgets, captivating enthusiasts with their ability to fly and capture stunning aerial photographs and videos. Early models were often small, toy-like devices with limited capabilities and flight times. However, as interest grew, manufacturers recognised the market potential and began producing more user-friendly and advanced drones tailored for photography and videography.

Figure 1: UAV use in agriculture.

3.4.2. First Commercial Applications

As drone technology advanced, its potential for commercial applications became evident. Industries such as agriculture, construction, filmmaking, and surveying quickly realised the benefits of utilising drones. In agriculture, drones equipped with sensors and cameras revolutionised crop monitoring, enabling farmers to assess plant health, identify problem areas, and optimise resource allocation. In construction, drones streamlined surveying and mapping processes, enhancing accuracy and efficiency on job sites. Filmmakers embraced drones for capturing breathtaking aerial shots, once possible only with expensive helicopter rentals. Drones also found applications in disaster management, search and rescue operations, and infrastructure inspection, transforming the way these tasks are performed.

3.5. Working Principles of Drones

Drone technology (Unmanned Aerial Vehicle Technology) refers to unmanned aircraft systems controlled via radio remote control devices or embedded programs. It encompasses comprehensive technologies such as flight control, navigation, sensing, communication, and mission execution. Its core lies in integrating hardware and software to achieve autonomous flight and task execution. Applications have expanded from military uses to civilian fields like agriculture, logistics, surveying, and rescue operations. [12]

The working principle of drone technology is based on aerodynamics, sensor fusion, and real-time communication between the aerial platform and a ground control station.

3.5.1. Core System Components

A drone system operates through the collaboration of two primary subsystems:

Flight Platform: Comprises the airframe, propulsion unit, sensors, and mission payloads, directly responsible for aerial operations. [12]

Ground Control System: Uses remote controls or computers to send commands and receive telemetry data from the drone. [12]

3.5.2. Functional Modules of the Flight Platform

Propulsion System

- Function: Converts electrical energy into mechanical thrust.
- Core Components [12]:
    - Brushless DC motors driving propellers.
    - Electronic Speed Controllers (ESCs) for precise motor speed regulation.
    - Carbon Fiber / Nylon Propellers to generate lift and thrust.

Power Management System

- Energy Storage: Lithium-polymer (Li-Po) or lithium-ion batteries provide chemical energy.
- Safety Monitoring:
    - Battery Management System (BMS) continuously monitors cell voltage and temperature, preventing overcharging and over-discharging.
    - Power Distribution Board (PDB) supplies high-voltage power to motors while stepping down to 5V/3.3V for precision electronics.
- Endurance Management: current/voltage monitoring modules estimate remaining flight time and trigger auto-return when battery levels are low.

Perception & Navigation System

Serves as the "senses" and "positioning capability," utilising sensors (e.g., GPS, IMU, cameras, LiDAR) to determine location, attitude, and environmental awareness, essential for autonomous flight.

Flight Control System (FCS)

Acts as the "brain," processing sensor data, executing control algorithms, maintaining stability, and responding to commands from ground stations or autonomous navigation modules.

Communication System

Functions as the "nervous system", enabling data links between the drone and ground control to transmit commands, telemetry, and real-time imagery.

- Communication Protocols:
  - MAVLink: A lightweight, open-source protocol for drones, now an industry standard. It enables efficient transmission of telemetry data, control commands, and waypoints.
  - Wi-Fi/HD Video Transmission: Used in consumer and cinematic drones for high-bandwidth video streaming (e.g., DJI's OcuSync/Lightbridge).
  - 5G/Cellular Networks: Supports beyond-visual-line-of-sight (BVLOS) operations and cloud-based control, offering broader coverage and lower latency.

3.5.3. Flight Principles

Drones adhere to fundamental aerodynamics:

- Lift: generated by rotating propellers via Bernoulli's principle and Newton's third law, counteracting gravity.
- Thrust: propeller-driven force enabling movement and directional control.
- Drag: air resistance reduced through streamlined designs.
- Weight: balanced by lift, impacts endurance and agility.

3.5.4. Flight Control and Navigation

- Altitude Control:

  - Sensor Fusion: Combines data from IMU, gyroscopes, accelerometers, barometers, and GNSS (e.g., GPS/BeiDou).
  - FCS Adjustment: Uses MCU-processed data to dynamically regulate motor output via ESCs.
- Autonomous Navigation:
  - Follows preset waypoints with real-time obstacle avoidance (radar/ultrasonic/vision sensors).
  - Employs SLAM (Simultaneous Localization and Mapping) for 3D environmental mapping.

3.5.5. Communication and Data Transmission

Commands transmitted via 2.4 GHz/5.8 GHz radio, Wi-Fi, or cellular networks.

Real-time FPV (First-Person View) streams HD footage to ground stations.

3.5.6. Mission Execution Capabilities

Payload Flexibility: Supports infrared cameras, LiDAR, multispectral sensors, etc.

Smart Features:

Auto-return (GPS-based).

Geofencing (no-fly zone restrictions).

3-axis gimbal stabilization.

3.6. Types of drones

3.6.1. By Structure:

Multirotor Drones:

- Quadcopters: 4 propellers, agile, ideal for aerial photography [13]
- Hexacopters/Octocopters: Redundant design, enhanced safety and payload capacity [14], [15]
- Fixed-Wing Drones: Wing-generated lift, long endurance, suited for surveying
- Hybrid VTOL (Vertical Takeoff and Landing) Drones: Combines rotor agility with fixed-wing efficiency [16]
- Racing Drones, sometimes listed as a separate category: Lightweight, high manoeuvrability, for competitive sports

As shown in Figure 2, fixed-wing drones, rotary-wing drones, and hybrid drones are three types of drones or unmanned aerial vehicles (UAVs) that are commonly used for various applications, including in the construction and maintenance industries. Each type of drone has its unique advantages and disadvantages, and choosing the right drone for a specific application depends on several factors, such as the size of the area to be covered, the required payload capacity, and the environmental conditions in which the drone will be operated. Fixed-wing drones are ideal for covering large areas quickly [11], while rotary-wing drones are more suitable for close-range inspections and operations in confined spaces [13], [14], [15]. Hybrid drones offer a more versatile and adaptable solution but may be more complex and expensive than fixed-wing or rotary-wing drones [16].

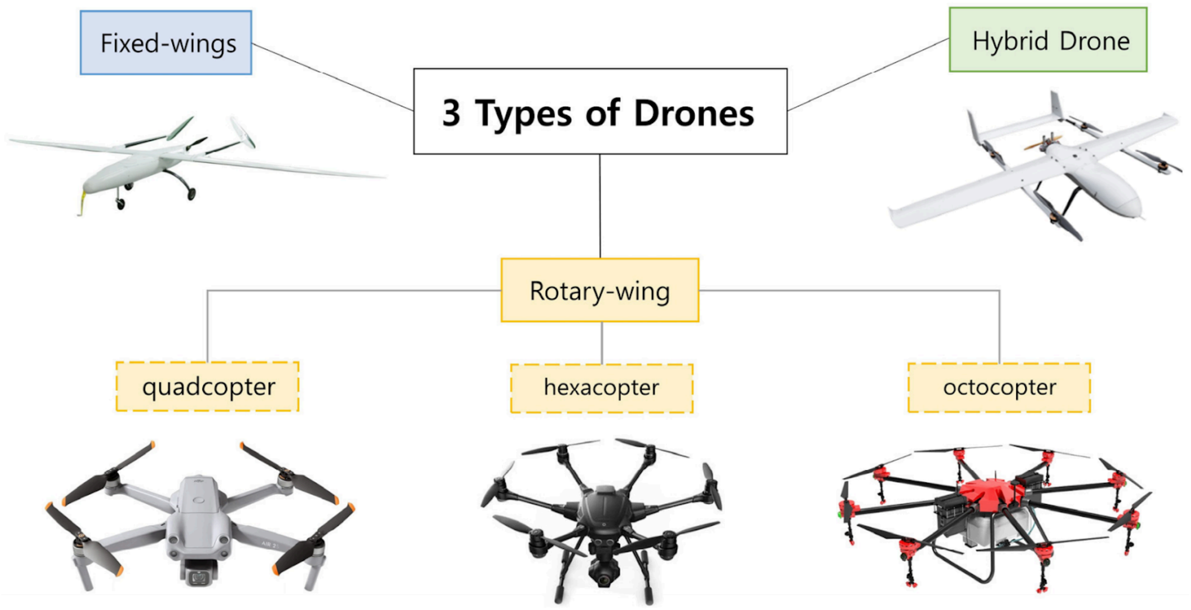

Figure 2: Different types of drones.

3.6.2. By Power System:

- Lithium Battery: lightweight, dominant in consumer drones.
- Fuel-Powered: extended endurance, noisy.
- Hydrogen Fuel cell: eco-friendly, efficient in cold environments.
- Solar-Powered: theoretically unlimited endurance, relies on solar panels.

3.6.3. By sensing system

Cameras help drones take photos and videos from the sky. These are used in real estate, construction, and farming.

Sensors detect heat, light, or motion. Some stop drones from crashing. A special LiDAR sensor uses light pulses to create detailed 3D maps of land or buildings. [17]

LiDAR, short for Light Detection and Ranging, sends rapid light pulses and measures how long they take to return. This helps drones accurately map areas, even though trees or fog.

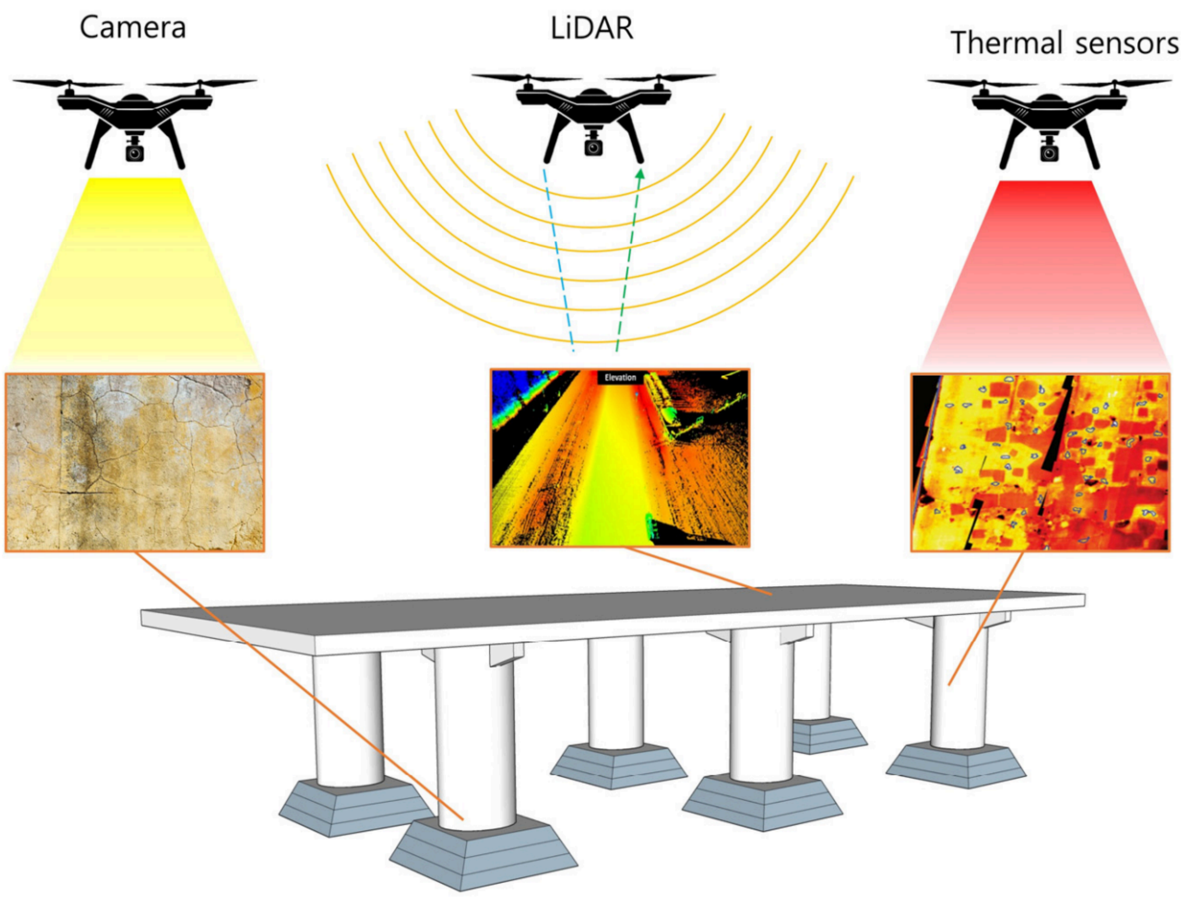

Figure 3: Different types of sensing systems for drones.

Technological Advancements

4. Technological Advancements

The rapid evolution of drone technology brought about significant advancements in various areas. Battery life improved, enabling longer flight times and increased operational range. Lightweight materials and compact designs made drones more portable without sacrificing performance. GPS integration allowed for precise navigation and autonomous flight capabilities. The introduction of obstacle avoidance systems and collision sensors enhanced safety and reliability. Furthermore, advancements in camera and imaging technology led to higher-resolution imagery and the ability to capture thermal or multispectral data, unlocking new possibilities in industries like agriculture, environmental monitoring, public safety, and construction. [18]

4.1. Key Technological Breakthroughs

- Materials & Structure: carbon fibre composites reduce weight, military-grade designs withstand extreme conditions.
- Obstacle Avoidance: 360° detection via fused LiDAR, vision, and ultrasonic sensors.
- Energy Optimisation: quick-swap batteries, hydrogen cells enable 2-hour flights.
- Autonomy & AI: Advanced SLAM, deep learning for object recognition, swarm coordination.

The foundation of the drone market growth lies in continuous technological innovation. Breakthroughs in artificial intelligence, machine learning, and edge computing have enhanced drone capabilities in navigation, image processing, and decision-making. AI-powered drones can identify objects, avoid obstacles, and plan optimised routes autonomously.

The integration of 5G networks is another critical enabler, facilitating real-time data transmission and seamless communication between drones and ground control systems. This connectivity allows for Beyond Visual Line of Sight (BVLOS) operations, expanding drone usage for mapping large areas, surveying, and long-range logistics missions.

Additionally, the introduction of hybrid propulsion systems and lightweight composite materials has increased endurance and payload capacity. New technologies like swarm intelligence are enabling multiple drones to collaborate on missions, whether for search and rescue, precision agriculture, or military reconnaissance.

The emergence of counter-UAV technologies has also become a vital part of the ecosystem, ensuring safe integration of drones into urban airspace and addressing security concerns.

4.2. Emerging Technologies for Construction Applications

In addition to foundational drone technologies, the construction sector is rapidly adopting advanced drone technologies that go beyond conventional aerial photography and mapping. Several systems are now becoming standard in professional construction workflows, particularly in renovation, infrastructure, and large-scale project environments.

- High-precision positioning technologies such as Real-Time Kinematic (RTK) and Post-Processed Kinematic (PPK) systems: enable centimeter-level accuracy, supporting reliable mapping, earthwork calculations, and alignment with engineering coordinate systems.
- LiDAR (Light Detection and Ranging): increasingly used for detailed 3D scanning of existing buildings, terrain modelling, volumetric analysis, and generation of dense point clouds suitable for BIM integration. This technology has the ability to capture complex geometries and operate independently of lighting conditions, making it particularly valuable in renovation and retrofit projects.
- Multi-sensor drone platforms integrating RGB, thermal, multispectral, and LiDAR sensors: allow more comprehensive site diagnostics, including façade inspections, roof assessments, moisture detection, and infrastructure monitoring through layered data analysis.
- Integration of Artificial intelligence: progressively embedded into drone data processing workflows, AI supports automated defect detection, crack identification, thermal anomaly recognition, and change monitoring across various project timelines in construction operations.
- Integration with Building Information Modelling (BIM) and digital twin environments: enable drone-generated data to update project models and enhance lifecycle documentation and asset management processes.

- Drone-in-a-Box systems: automated, weatherproof, and self-contained docking stations for UAVs that introduce higher levels of automation through remotely managed, scheduled missions. These systems allow for continuous site monitoring and Beyond Visual Line of Sight (BVLOS) operations without on-site personnel, improving efficiency and standardisation in large or long-duration construction projects
- Swarm technologies: enable coordinated site monitoring across large-scale projects, improving data capture efficiency and temporal consistency.
- Edge computing integration: allows drones to process data in-flight, reducing latency and accelerating decision-making processes.

These emerging technologies reflect the ongoing digital transformation of the construction sector, positioning drone systems as integral components of modern project delivery and infrastructure management.

4.3. Strategic Technology Roadmap for Drone Integration in Construction (2025–2030)

The Strategic Technology Roadmap synthesizes findings from: the literature review on emerging drone technologies and construction digitalisation trends, analysis of the European regulatory evolution framework including EASA regulations and U-space implementation, that are discussed in previous sections of this report, as well as empirical insights collected from consortium partners.

The roadmap reflects already observable technological, regulatory, and organizational adoption patterns within the European construction ecosystem and is aligned with current digital transition models in construction and projected technology maturity trajectories documented in recent EU policy and industry studies (including the EU Digital Decade 2030 targets [40], the Renovation Wave Strategy [41], and Drone Strategy 2.0 [42]. It does not represent fixed predictions, but rather structured scenarios intended to guide training and competency development.

The evolution of drone applications in the construction and renovation sector can be structured across three progressive phases, reflecting technological maturity, regulatory development, and workforce capability.

4.3.1. Phase 1: Operational adoption (Current State)

Drone systems are primarily used for surveying, progress monitoring, façade inspection, stockpile measurement, and safety assessment. Operations are mostly conducted within the Open and Specific categories, relying on RTK positioning, photogrammetry, and thermal inspection. Data integration with BIM and construction management platforms exists but remains partially implemented and often dependent on specialised personnel.

4.3.2. Phase 2: Integrated digital workflows (2026–2030)

During this phase, drone operations increasingly integrate with BIM, geographic information systems (GIS), and digital twin environments. Automated repeatable missions, Drone-in-a-Box systems, AI-assisted defect detection, and structured data lifecycle management become standard practice. Construction companies shift from isolated drone flights to continuous data-driven monitoring cycles. Interoperability between drone outputs and construction software platforms becomes a key capability requirement.

4.3.3. Phase 3: Autonomous and intelligent ecosystems (2030–2035)

Drone systems evolve toward higher autonomy, BVLOS-enabled site monitoring, edge computing, and semi-autonomous inspection routines. AI-driven analytics support predictive maintenance, automated compliance checks, and advanced renovation diagnostics. Drone data becomes embedded in lifecycle asset management processes, contributing to sustainability monitoring and long-term infrastructure planning.

Across all phases, the critical enabling factor is workforce competence. Technological advancement must be accompanied by structured upskilling in digital literacy, regulatory awareness, and data integration.

Co-funded by the European Union

Regulatory Landscape

5. Regulatory Landscape

As drones soared in popularity, governments worldwide recognised the need for regulations to ensure safe and responsible usage. Regulatory frameworks emerged to address concerns regarding privacy, airspace congestion, and the potential misuse of drones. They include guidelines for drone registration, pilot licensing, flight restrictions, and operational limitations. While navigating these regulations can be somewhat challenging, they also provide a framework for the safe integration of drones into society and the realization of their full potential. [18]

The policy guidelines for the development of the drone sector in Europe are derived from general transport and mobility documents, as well as specific regulations pertaining to drones (Figure 4). The first European Commission's document relevant for drones is the Staff Working Document on "Towards a European Strategy for the Development of Civil Applications of Remotely Piloted Aircraft Systems" (EC, 2012) published in 2012 which reviewed potential benefits and challenges of drones and their potential integration into European airspace. It was followed by the Commission's Communication "A new era for aviation" (EC, 2014) which set up the foundations of the EU policy in the field of drones.

An Aviation Strategy for Europe aimed to create a comprehensive framework to support the development of the European aviation sector (EC, 2015). It proposed to create a basic legal framework for the safe development of drone operations. In addition, the Commission adopted in 2019 a series of rules regulating operations with drones (EC, 2019b; EC, 2019a) and adopted in 2021 three Implementing Regulations on U-space, which provide the air traffic management system for drones (EC, 2021a; EC, 2021b; EC, 2021c). In addition, the Commission also supported the development of standard scenarios to reduce the administrative burden related to the operational authorisation process (EC, 2020b). [19]

In the Commission's Sustainable and Smart Mobility Strategy (EC, 2020d), a document that outlines an ambitious roadmap to ensure a sustainable, smart, and resilient future for European transport, the Commission announced its plans to develop a Drone Strategy 2.0 for a smart and sustainable unmanned aircraft ecosystem in Europe. The strategy set out possible ways to guide the further development of this technology and its regulatory and commercial environment (EC, 2022a). The document is accompanied by a Staff Working Document (EC, 2022b) which provides an overview of the Commission services' assessment of the challenges that the drone sector faces as well as the analysis and data underpinning the Drone Strategy [19].

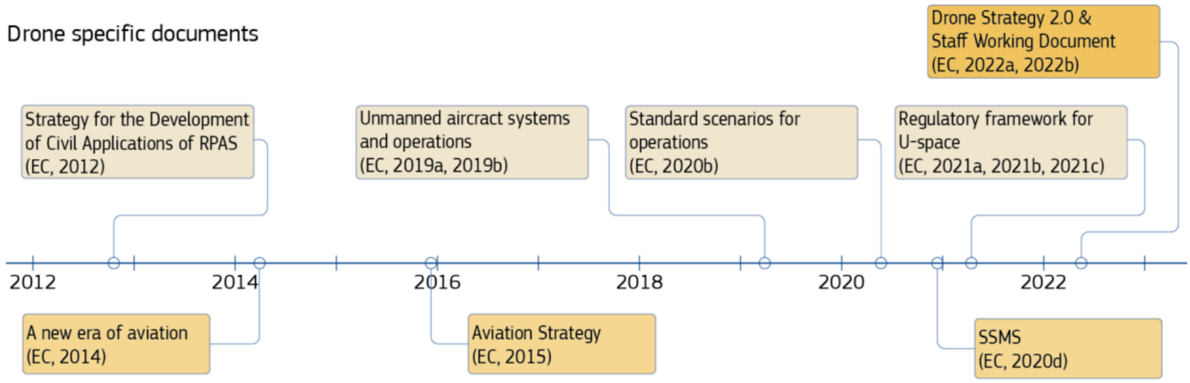

Figure 4: Timeline for drone related EC documents.

5.1. Regulatory Framework Current Status - Drone Integration in the Construction Sector

The European drone ecosystem is governed by a harmonised regulatory framework that has been established under the authority of the European Union Aviation Safety Agency (EASA). Since 2019, all EU Member states have applied a risk-based operational model, ensuring uniform safety standards that enables scalable commercial drone operations across the European sky.

The foundational legal instruments remain:

- Commission Delegated Regulation (EU) 2019/945 (UAS product requirements and CE class markings)
- Commission Implementing Regulation (EU) 2019/947 (operational rules and pilot competency requirements)
- This framework introduced three operational categories:
- Open Category: covers low-risk operations under predefined limitations
- Specific Category: covers medium-risk operations requiring risk assessment (e.g., SORA)
- Certified Category: covers high-risk operations comparable to manned aviation

Since 2023–2024, the framework is no longer in an introductory phase but has evolved significantly and moved from foundational adoption to actual practical implementation and operational scaling. More specifically, updates include:

- Amendments to Regulation (EU) 2019/947 clarifying operational authorisations and transitional provisions.
- Updated EASA Acceptable Means of Compliance and Guidance Material (AMC/GM).
- Increased harmonisation of digital operational authorisation processes.
- Wider practical application of Standard Scenarios (STS-01 and STS-02).

Regarding the European U-space framework, it is now at an operational deployment phase. As of 2024-2025 several EU Member States, including Spain, Italy, France and Germany, have designated U-space airspace in selected urban and controlled environments, particularly in dense urban environments, areas near airports or high-risk or congested airspace zones.

U-space as was mentioned above, enables a digitally managed airspace environment in which drone operations can be safely integrated alongside other airspace users. Through U-space services, operators can obtain digital flight authorisations in designated areas, ensuring that planned missions are automatically assessed against airspace restrictions and other traffic. Drones operating within U-space are required to transmit network identification (through integrated Remote ID trackers), allowing authorities and relevant stakeholders to identify and monitor operations in real time. In addition, traffic information and deconfliction services support safer operations by providing situational awareness and helping prevent conflicts between multiple drone flights or with other airspace users. These services are delivered through certified U-space Service Providers (USSPs), which act as the digital interface between drone operators and the broader air traffic management system.

For the construction sector, most professional activities fall within the Open (A2/A3) and Specific categories. More specifically construction sites usually require operations that are:

- Near uninvolved people.
- Close to structures and cranes.
- In controlled or restricted airspace.
- Beyond Visual Line of Sight (BVLOS) in linear infrastructure projects.

Under the Specific Category these operations are typically authorised using the Specific Operations Risk Assessment (SORA) methodology or through Standard Scenarios (STS-01 / STS-02). In this context to ensure regulatory compliance the requirements are:

- Conducting a Specific Operations Risk Assessment (SORA).
- Identifying Ground Risk Class (GRC).
- Identifying Air Risk Class (ARC).
- Defining mitigation strategies.
- Submitting documentation to the National Aviation Authority.

This means that construction professionals must acquire not only flight skills but also regulatory and risk management knowledge. Additionally, for construction projects located in urban or controlled environments, U-space integration is increasingly relevant. Construction operators must be able to understand digital airspace coordination and interaction with U-space Service Providers (USSPs).

Commercial Drone Applications

6. Commercial Drone Applications

Commercialisation has become one of the major growth drivers for the Drone Market. UAVs are being deployed across multiple industries to streamline operations and enhance data accuracy [20].

- Agriculture: Drones equipped with multispectral and thermal sensors monitor crop health, detect pest infestations, and optimise irrigation. These applications improve yield quality while reducing costs and environmental impact.
- Construction & Infrastructure: UAVs perform aerial mapping, progress tracking, and inspection of bridges, roads, and buildings. Real-time imaging enables faster decision-making and risk reduction.
- Energy & Utilities: The Drone (UAV) Market supports remote inspection of power lines, offshore platforms, and renewable energy installations. This reduces downtime and improves worker safety.
- Environmental Monitoring: Drones assist in tracking deforestation, wildlife, and natural disaster assessment, providing critical data for sustainability initiatives.
- Healthcare & Logistics: Drones are increasingly used for emergency medical supply delivery in remote areas, helping save lives during natural disasters or pandemics.

These commercial applications are supported by regulatory advancements and technological readiness, driving broader adoption across global markets.

6.1. Drone Technology Providers Today

In the construction sector the leading drone technology providers are:

- DJI and more specifically its enterprise division: widely adopted for mapping and inspection platforms.
- Skydio: Well-known autonomous navigation based on AI, in complex environments.
- Parrot: More focused on mapping and inspection applications.

Apart from drone technology hardware there are some companies worth mentioning that offer software platforms, focused on construction activities.

These platforms integrate drone data into BIM workflows, GIS systems, and digital project management tools. More specifically:

- Pix4D: offers photogrammetry and 3D modelling solutions widely used in surveying.
- DroneDeploy: offers cloud-based site documentation and analytics.
- Propeller Aero: is an earthworks and volumetric analysis platform.

6.2. Future Outlook

The future of the Drone Market is closely tied to advancements in AI, 5G, and sustainable technologies. As drones become more autonomous, intelligent, and interconnected, they will play a central role in shaping smart cities, defence systems, and digital economies.

Emerging trends such as urban air mobility, autonomous cargo drones, and AI-based mission planning will further expand UAV capabilities. Governments and enterprises are expected to increase collaboration to harmonize regulations and integrate drones into national infrastructure.

Over the next decade, the convergence of defence-grade reliability with commercial innovation will drive exponential growth in the drone and UAV market. These unmanned systems will not only serve as tools for data collection and logistics but also as strategic assets for sustainability, national security, and industrial automation [20].

The Drone Market has entered an era of sustained expansion, supported by rapid technological progress, diversified applications, and robust investments. Drones are no longer peripheral technologies, they are integral to the future of mobility, security, and digital transformation.

The future of drone applications in the construction sector will be shaped by increasing automation, system integration, and data intelligence. While current deployments already support surveying, inspection, and progress monitoring, the next phase of development will focus on greater operational autonomy and seamless integration into digital construction ecosystems.

Automation is expected to reduce the need for manual flight control, as pre-programmed missions, repeatable flight paths, and remote fleet management are becoming standard practice, particularly on large-scale projects. Additionally, advances in artificial intelligence will further enhance data processing capabilities.

In the longer term, improvements in sensor miniaturisation, battery efficiency, connectivity (including 5G), and regulatory harmonisation are expected to expand operational flexibility and enable more advanced use cases. As the construction industry continues its digital transformation, drone systems will evolve from supplementary tools to embedded components of standard project management and asset lifecycle processes.

The construction and renovation sector specifically future is not defined merely by drone market expansion, but by the depth of digital integration within project delivery systems. The competitive advantage will not derive solely from owning drone hardware, but from the ability to integrate drone-generated data into BIM workflows, automated reporting systems, and lifecycle asset management platforms. Consequently, the strategic priority shifts from equipment acquisition to competence development and interoperability capability.

Use of Drones in Construction

7. Use of Drones in Construction

Once considered an emerging technology, drones are now widely used across construction sites.

And construction companies are reaping the benefits, using drones in construction to cut costs, improve decision-making, and increase efficiency.

Construction drones are transforming the industry by providing faster, safer, and more cost-effective ways to do key tasks, including:

- Site surveys
- Progress monitoring
- Safety inspections
- Resource management

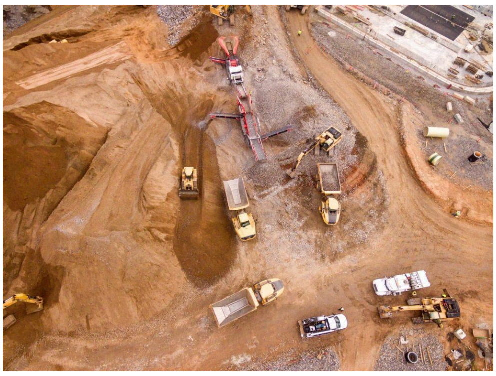

Figure 5: Drone POV of construction site.

There are various types of drones used in the construction industry for various purposes. In reference [10], the study conducted surveys from many construction companies to find out how drones were used for their construction projects and it showed that the most popular use of drones was in capturing progress photos, followed by taking promotional videos, conducting inspections, and enhancing site management (Figure 6).

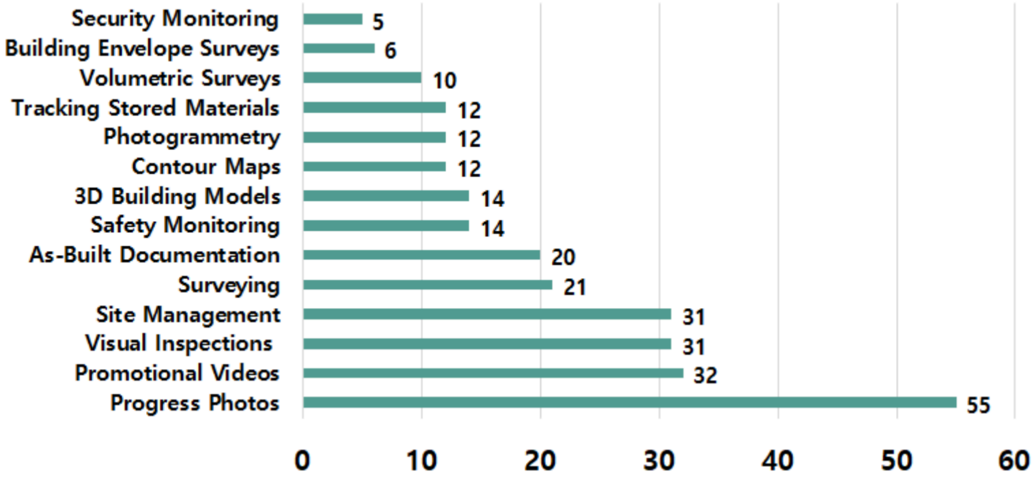

Figure 6: Drone use purposes in the construction industry.

AI-driven mapping software has developed alongside drone technology. This software contains powerful systems for processing a drone's raw visual data to provide detailed maps of construction sites.

And the adoption of drones in construction is only going to grow. The global construction drone market is projected to reach $11.96 billion by 2027, and a whopping $19 billion by 2032.

Figure 7: Drone operator on construction site.

One of the main reasons to use a drone in construction is to capture quick, accurate visual data of a site [21].

With the ability to automate data collection and integrate with construction software, drones are now a key component of modern construction workflows.

Construction drones can generate a range of deliverables, including high-resolution aerial imagery, 2D orthomosaic maps, 3D models, digital elevation models (DEMs), and LiDAR scans, providing precise data for project managers and stakeholders.

7.1. Drone applications in construction

Construction companies use these outputs in a range of ways, from site surveying to progress monitoring, to safety inspections.

Below are a few common uses for drones in construction. More detailed overview of the benefits of the use of drones in construction is given in Annex 3.

7.1.1. Site and Land Surveying & Mapping

Choosing the right site for any construction project is one of the first steps before constructing a structure. It involves assessing various potential sites to determine the most suitable location for the project. Drones play a significant role in this process by providing valuable data and insights through aerial imagery and data collection. One the primary advantages of using drones for site selection and evaluation is the ability to capture high-resolution aerial imagery. Drones equipped with cameras can capture detailed photographs and videos of the prospective sites from different angles and altitudes. [21]

This imagery provides a comprehensive overview of the site, allowing project managers, architects, and engineers to assess its characteristics and potential. Drones equipped with high-resolution cameras and LiDAR sensors can swiftly capture detailed aerial imagery and topographic data of construction sites. This data facilitates the creation of accurate 2D maps and 3D models, streamlining the planning and design phases.

Mapping with drones encompasses the generation of accurate maps and models of the construction site using aerial imagery and photogrammetry techniques. High-resolution aerial imagery captured by drones covers large areas efficiently, providing a visual representation of the site’s features. Photogrammetry algorithms process the overlapping images to create 2D and 3D maps, including topographic maps that depict elevations, contours, slopes, and other topographic features.

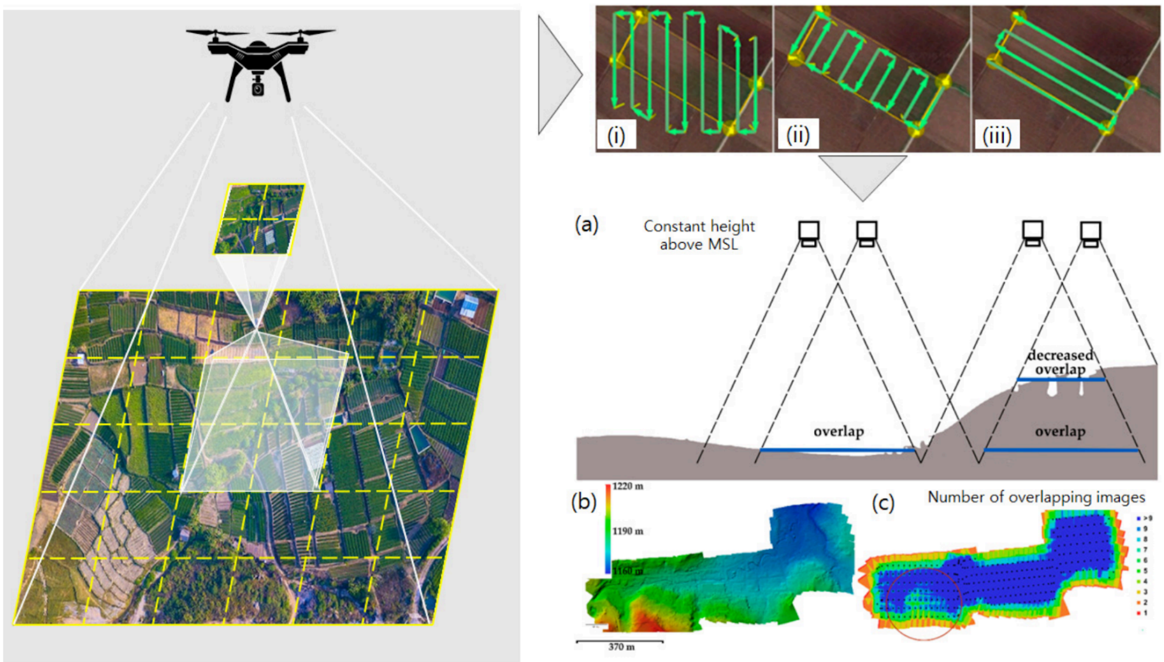

Figure 8: Generating a digital terrain model.

Surveying & Mapping Use Cases:

- Generating orthomosaic maps: to provide an accurate, up-to-date view of the entire construction site.
- Creating 3D terrain models: to help with earthwork calculations and site planning.
- Conducting topographic surveys. to assist in infrastructure development and site preparation.

7.1.2. Progress Monitoring

Regular drone flights enable project managers to monitor construction progress in real time, ensuring adherence to schedules and budgets. Aerial imagery provides a comprehensive view of the site, aiding in the identification of potential delays or issues. Drones play a crucial role in quality control by capturing high-resolution imagery and data that allow for thorough inspections and defect detection. The detailed imagery enables inspectors to identify even minor defects, such as cracks, corrosion, or surface imperfections, that might be missed during ground inspections. By comparing the captured data with the construction plans or 3D models, inspectors can quickly identify any deviations or errors in the construction process. This early detection of defects enables timely rectification, ensuring that the project meets the required quality standards. Drones also facilitate the systematic documentation and tracking of identified defects, providing a clear record of issues that need to be addressed [22].

Progress Monitoring Use Cases:

- Documenting weekly progress: to capture aerial photographs for side-by-side comparisons.
- Comparing as-built conditions: to identify discrepancies between plans and actual construction.
- Sharing visual updates. to provide stakeholders with real-time insights into project status.

7.1.3. Safety Inspections

Drones can access hazardous or hard-to-reach areas, conducting safety inspections without endangering personnel. They identify potential risks, such as structural weaknesses or compliance issues, contributing to a safer work environment. Safety monitoring using drones during the construction phase has emerged as a valuable tool for enhancing safety practices and mitigating potential hazards. Drones equipped with advanced cameras, sensors, and data processing capabilities offer several benefits for safety monitoring in construction. By capturing high-resolution imagery and videos, drones can identify unsafe conditions such as unstable structures, debris, equipment malfunctions, or improper use of personal protective equipment. The aerial perspective allows inspectors to assess the overall safety of the site, identify potential risks, and take necessary preventive measures. Figure 9 shows a case study for using a drone for safety monitoring in a high-rise building construction project [23].

Figure 9: UAV images from safety monitoring of construction site.

Safety Inspection Use Cases:

- Inspecting scaffolding and high structures: to reduce the need for manual inspections at height.
- Monitoring compliance with safety protocols: to ensure workers adhere to OSHA regulations.
- Detecting environmental hazards: to identify gas leaks, unstable structures, or unsafe conditions.

7.1.4. Equipment Tracking

By providing an aerial perspective, drones assist in tracking the location and utilization of equipment on large construction sites, optimizing asset management and reducing downtime.

Equipment Tracking Use Cases:

- Locating machinery across expansive sites: to reduce time spent searching for misplaced equipment: to help schedule maintenance and prevent unexpected breakdowns.
- Preventing unauthorized use or theft: enhances security by tracking movement and usage patterns [23].

7.1.5. Stockpile Measurement

Drone data enables the precise measurement of stockpiles, such as aggregates or soil, using photogrammetry techniques. This automation reduces the need for manual surveys and minimises errors [23].

Stockpile Measurement Use Cases:

- Calculating volumes of materials: to improve inventory management and ordering accuracy.
- Assessing material usage rates: to help optimise supply chain efficiency.
- Planning material orders: to reduce waste and ensure resources are available when needed.

7.1.6. Quality Control

High-resolution drone imagery allows for detailed inspections of construction quality, identifying defects or deviations from plans early in the process [23].

Quality Control Use Cases:

- Detecting misalignments in structural components: to ensure construction accuracy before major work continues.
- Ensuring uniformity in installations: to identify inconsistencies in materials or finishes.
- Verifying compliance with building codes: to provide documentation for regulatory approvals.

7.1.7. Environmental Monitoring

Drones equipped with specialized sensors monitor environmental factors, ensuring compliance with regulations and minimizing ecological impact [23].

Environmental Monitoring Use Cases:

- Measuring air quality: to detect pollutants and ensures workplace safety.
- Monitoring water runoff and sediment control: to help prevent environmental damage from construction activities.
- Assessing noise levels: to ensure compliance with local noise regulations.

7.1.8. Security Surveillance

Regular drone patrols enhance site security by monitoring for unauthorized access, theft, or vandalism, especially during off-hours [23].

Security Surveillance Use Cases:

- Conducting perimeter surveillance: to help secure construction sites from intruders.
- Identifying unauthorized personnel: to track movements and alerts security teams.
- Deterring potential intruders: visible drone presence discourages theft and vandalism.

7.1.9. Marketing & Client Updates

Aerial footage captured by drones serves as valuable marketing material, showcasing project progress and completed works to clients and stakeholders [23].

Marketing & Client Update Use Cases:

- Creating promotional videos: to highlight projects for marketing and investor presentations.
- Providing clients with visual progress reports: to keep stakeholders informed with professional aerial imagery.
- Documenting milestones: to preserve key project achievements for historical records.

7.1.10. Infrastructure Inspections

Drones facilitate the inspection of existing infrastructure, such as bridges and roads, to assess conditions and plan maintenance or integration with new projects [23].

Infrastructure Inspection Use Cases:

- Inspecting bridge integrity: to identify cracks, corrosion, and structural weaknesses.
- Assessing road surface conditions: to prioritize maintenance and resurfacing projects.

- Evaluating utility lines: to ensure infrastructure is compatible with new construction.

7.2. Drone Applications in Building Renovation and Retrofitting

Drone applications in building renovation and retrofitting presents distinct operational and technical requirements. Renovation projects involve existing structures, material deterioration, restricted access, heritage constraints, and energy performance considerations. When drone technology is properly integrated in such projects, it can provide non-invasive, efficient, and high-resolution assessment capabilities that support renovation planning, safety evaluation, and performance verification.

7.2.1. Façade and Building Envelope Assessment

Façade and envelope inspection represents one of the most significant drone applications in renovation contexts. Unlike new-build projects, renovation requires detailed condition assessment of existing materials and structural elements.

Typical use cases include:

- Documentation of crack mapping and surface deterioration.
- Assessment of palling and concrete degradation.
- Mapping of roof condition (tiles, waterproofing membranes, ponding areas).
- Thermal surveys for insulation defects and thermal bridges.
- Moisture intrusion detection.
- Window and door alignment and condition assessment.

To ensure reliable results, thermal inspections must follow proper methodology, that includes environmental condition control, emissivity settings, and appropriate timing (e.g., temperature differentials).

In renovation workflows, data collected from drones can, also, be utilised to support the preparation of defect registers, repair prioritisation, and technical reporting prior to intervention.

7.2.2. Heritage and Complex Building Documentation

Historic buildings and buildings that are considered architecturally complex require non-invasive documentation techniques that minimise physical contact and scaffolding installation.

Photogrammetry that is based on the use of drones enables:

- High-resolution documentation of façades, ornaments, and structural details.
- Creation of detailed 3D models for restoration planning.
- Condition assessment of elevated or fragile elements.

Operations in heritage contexts often require controlled flight planning, strict safety measures, and compliance with the requirements of the relevant conservation authority. Constraints about privacy and operations in urban environments must also be carefully taken into consideration. The data collected from drones, in these cases, supports restoration studies, preservation planning, and accurate geometric reconstruction.

7.2.3. Energy Efficiency Audits and Retrofit Planning

In renovation projects a central objective is energy performance improvement. Thermal sensors mounted on drones can support large-scale building envelope analysis, particularly for multi-storey structures.

Use cases include:

- Evaluation of thermal envelope.
- Identification of insulation gaps.
- Detection of thermal bridges (localized areas where insulation is interrupted or penetrated leading to significant heat loss, condensation, potential mould growth, and structural damage).
- Identification of air leakage pattern.·
- Comparison of the performance before-and-after the renovation.
- Integration with Energy Performance Certificate (EPC) processes.

Energy audits that are assisted by drones enable rapid, non-contact assessment of large surfaces, contributing to retrofit planning that is based on accurate data.

7.2.4. Indoor operations

Although drones are primarily associated with outdoor operations, certain renovation scenarios can benefit from controlled indoor use. In large interior spaces such as atriums, industrial halls, or roof structures, small, protected UAV platforms (drone in a cage) can be utilized to support documentation and inspection.

Such use cases include:

- Roof structure assessment from interior vantage points.
- Documentation of HVAC (Heating, Ventilation & Air Conditioning) routing and overhead installations.
- Interior façade or ceiling inspections in high-volume spaces.
- Documentation of underground wastewater infrastructure

Indoor operations require enhanced safety protocols, including propeller protection, defined exclusion zones, visual observers, and careful assessment of lighting, dust, and GPS-denied environments.

7.2.5. Pre-Renovation Conditions Assessment

Before renovation begins, comprehensive documentation of existing conditions is essential. Drone systems support baseline data collection to identify visible deterioration and support engineering analysis.

Use cases include:

- High-resolution 3D scanning of existing buildings.
- Creation of baseline datasets for renovation planning.
- Identification of structural deformation indicators.
- Documentation of inaccessible or hazardous areas.
- Support to preliminary safety assessments.

Drones can be used to evaluate deteriorated structures before workers access them, reducing exposure to risk in unstable/unsafe environments.

7.2.6. MEP Systems Assessment

During renovation planning, drone inspections can also support the assessment of a building MEP (Mechanical, Electrical & Plumbing) system. These applications assist in identifying malfunctioning components, overheating modules, or installation defects before the system upgrades.

Typical use cases include:

- Inspections of rooftop HVAC (Heating, Ventilation & Air Conditioning) units.
- Assessment of exhaust stack and external piping.
- Inspection of solar PV using thermography and string-level anomaly mapping in photovoltaic installations.

7.3. Representative Drone Platforms for Construction

Figure 10: Quadcopter used on construction site.

In construction environments there is currently a range of drone platforms deployed, depending on the scale of the construction project, the inspection requirements, and expectations regarding accuracy. Drone selection is not purely a technical decision, but a strategic one linked to company capability and project profile. The selection of the most suitable platform in professional construction workflows is typically driven by drone's payload capability, positioning precision, environmental robustness, and compatibility with the data processing software systems that are used. More specifically it requires evaluation of multiple technical and operational parameters:

1. Project type and scale:
    - Small urban renovation vs. large infrastructure site.
    - Façade inspection vs. terrain mapping

   - Frequency of data capture (one-off vs. repeated monitoring)
2. Required accuracy:
   - Standard visual documentation.
   - Survey-grade accuracy with RTK/PPK.
   - LiDAR-based precision modelling.
3. Environmental conditions:
   - Urban density and GNSS signal reliability.
   - Wind tolerance requirements.
   - Dust, temperature, and weather exposure.
   - Indoor vs. outdoor operations.
4. Regulatory constraints:
   - Operations over or near people.
   - Proximity to airports or restricted airspace.
   - Need for “Specific” category authorization.
   - Night or automated operations.
5. Budget and organisational capacity:
   - Initial equipment investment.
   - Processing software licensing costs.
   - Training requirements.
   - Insurance and compliance costs.
   - In-house operation vs. outsourcing to service providers.

Examples of globally used construction drones on the market [23]:

7.3.1. The Skydio X10

Skydio Delivers a Breakthrough for Enterprise Drones with the Launch of Skydio X10

The Skydio X10 is a professional autonomous drone designed for a wide range of applications, including construction site monitoring and inspection. Equipped with multiple high-resolution cameras and advanced AI capabilities, it offers professional-grade obstacle avoidance and autonomous flight features.

Why suitable for construction: The X10’s advanced obstacle avoidance and autonomous capabilities make it ideal for navigating complex construction sites, enabling comprehensive data collection with minimal manual intervention.

Key Specifications:

- Weight: 4.65 lbs (2.11 kg).
- Flight time: 40 minutes.
- Camera: 1" 50MP wide sensor with 4K video, telephoto zoom, and thermal imaging capabilities.
- Autonomy: AI-powered obstacle avoidance with true 360° environmental awareness and autonomous flight capabilities.
- Thermal imaging: Teledyne FLIR Boson+ sensor with 640×512 resolution.

7.3.2. The Freefly Astro Max

The Freefly Astro Max is a robust industrial drone designed to handle demanding tasks like LiDAR scanning, aerial photogrammetry, and infrastructure inspection. With a significant increase in payload capacity and thrust compared to its predecessors in the Astro line, the Astro Max has upgraded versatility and performance for complex construction projects.

Why suitable for construction: The Astro Max's high payload capacity and compatibility with advanced sensors make it ideal for detailed mapping, surveying, and inspection tasks on construction sites.

Key Specifications:

- Flight time: Up to 39 minutes with no payload.
- Maximum payload capacity: 6.6 lbs (3 kg).
- Weight: 6.8 pounds (3,095 g).
- Camera: Various options including the Sony LR1 Payload, which has 61MP resolution and a range of lens options including 24mm, 35mm, 50mm, and 75mm.
- Durability: Tested to IP43.

7.3.3. The Parrot ANAFI USA

The Parrot ANAFI USA is a compact drone offering advanced imaging capabilities, including thermal imaging, making it suitable for a range of inspection tasks on construction sites.

Why suitable for construction: The ANAFI USA's thermal imaging capabilities and compact design make it ideal for detailed inspections and hard-to-reach areas.

Key Specifications:

- Flight time: Up to 32 minutes.
- Weight: 1.1 pounds (500 g).
- Camera: 32x zoom, 4K HDR video, 21 MP photos.
- Thermal imaging: FLIR Boson 320×256.

7.3.4. DJI Mavic 3

Compact enterprise drones are also increasingly used in renovation and retrofit projects. The DJI Mavic 3 Thermal, is adrone equipped with a high-resolution camera, thermal imaging sensors and mechanical shutter, making it ideal for mapping and surveying tasks in construction.

Why suitable for construction: DJI Mavic 3 Thermal integrates RGB and thermal imaging sensors in a lightweight platform, making it particularly useful for façade assessments, energy audits, rooftop inspections, and building envelope diagnostics.

Key Specifications:

- Flight time: Up to 45 minutes.
- Weight: 2 pounds (900 grams), without battery.
- Camera: 20MP wide-angle with 4/3 CMOS sensor.
- Video resolution: Up to 5.1K/30fps.

7.3.5. DJI Matrice 300/350 RTK

Enterprise-level multirotor systems such as the DJI Matrice 300/350 RTK are widely used in complex construction and infrastructure projects due to their modular payload capacity and RTK positioning capabilities.

Why suitable for construction: These platforms support thermal sensors, high-resolution RGB cameras, and LiDAR units, making them suitable for survey-grade mapping, façade inspection, and advanced reality capture tasks.

Key Specifications:

- Flight time: 55 minutes.

- Durability: IP55 rating.
- Camera: Compatible with a range of payloads, including the Zenmuse H20 series, which features a 20MP zoom camera, a 12MP wide camera, and a laser rangefinder.
- Transmission system: DJI O3 Enterprise Transmission.

Worth mentioning here are also fixed-wing platforms such as the eBee class systems which are most suitable for large-area mapping applications, including terrain modelling and infrastructure corridors. They are commonly used due to their extended flight endurance and coverage efficiency.

Table 1: Comparison table of types of drones.

	MULTIROTOR	VTOL	FIXED WING
Price	Ⓢ	Ⓢ Ⓢ Ⓢ	Ⓢ Ⓢ
Range	★ ☆ ☆	★ ★ ☆	★ ★ ★
Maturity level			
Adoption level in construction			
Productivity	⚙ ⚙	⚙ ⚙ ⚙	⚙ ⚙ ⚙
Payload weight	▣ ▣ ▣	▣ ▣	▣
Use cases	• Smaller areas • 3D structures • Inspection • Surveillance	Surveying large areas over difficult terrain	Surveying large areas
Communication	• Radio link (average 10–20 km in good conditions) • Cellular connectivity (limited to range of a telecom broadcast tower) • Satellite communication (near global coverage, the most expensive solution)		
Power supply	• Batteries (~ 30 min for multirotor | ~ 60 min for VTOL | > 60 min for fixed wing) • Tethered (a few days – a few weeks) • Hybrid: - Gasoline + battery (3–5 hours flight time) - Hydrogen + battery (–3 hours flight time)		
Positioning	• Standard GNSS (5–10 meter accuracy) • Survey grade GNSS receiver including RTK, RTN, PPK or PPP (1–5 cm accuracy)		
Sensors	• RGB (24–48 Mpx, 1-inch sensor: full frame, higher resolution and sensor size have significant impact on result quality) • LiDAR (typical precision is around 2–3 cm, accuracy range between 2–10 cm, can be merged with RGB sensor for generating colored point clouds) • Thermal sensors (640 x 512 resolution is the current standard of high-end solutions) • Multispectral (capturing data in visible spectrum and, in addition, in near-infrared (NIR), to gather data about vegetation health) • GPR (Ground Penetrating Radar, allowing the acquisition of information about what is beneath the surface) • Gas detectors (Optical Gas Imaging, thermal cameras, and other particle detectors)		
Safety systems	• Obstacle avoidance sensors • ADS-B transceiver • FLARM • Parachute		

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Adoption of drones and digital technologies

8. Adoption of drones and digital technologies

8.1. Elements and components of digital transition and recognising the skill gap

Digital transformation that comes with the introduction of new technologies is arriving at an increasing pace. This transformation entirely changes processes, workflows, and ways of doing business. Digital transformation in the construction industry is especially important as companies struggle to reach higher levels of efficiency and profitability. Learning from other industries, the transformation process itself should be considered an obligation, and the question should be one of when, not if. Implementation at an earlier stage will allow companies to be more competitive in a market which is seeing an increasing number of technology startups.

At the same time, the construction industry is considered one of the more challenging environments in which to introduce digital transformation. On one hand, this is related to the demographic and structural situation of the sector, which is often resistant to change. On the other hand, the complexity of large-scale construction projects makes it difficult to introduce new solutions which will not bring a return on investment right out of the box.

Adopting digital technologies is a long-term process, and the related cost and time savings are often not directly visible in the construction budget as the benefits are generally long-term and related to safety and risk avoidance, which are difficult to measure. However, compared to other construction technologies, drones are relatively easy to implement in a pilot scheme. The challenge begins when organisations want to scale the use of drones and other technologies beyond an isolated proof of concept or pilot project. Companies aiming to do that largely fail to avoid a fundamental mistake: They tend to focus on moving current workflows and methods into the digital realm, which can significantly limit the benefits of data integration. Instead, digital transformation brings an opportunity to completely redesign existing processes to remove inefficiencies and bottlenecks [24].

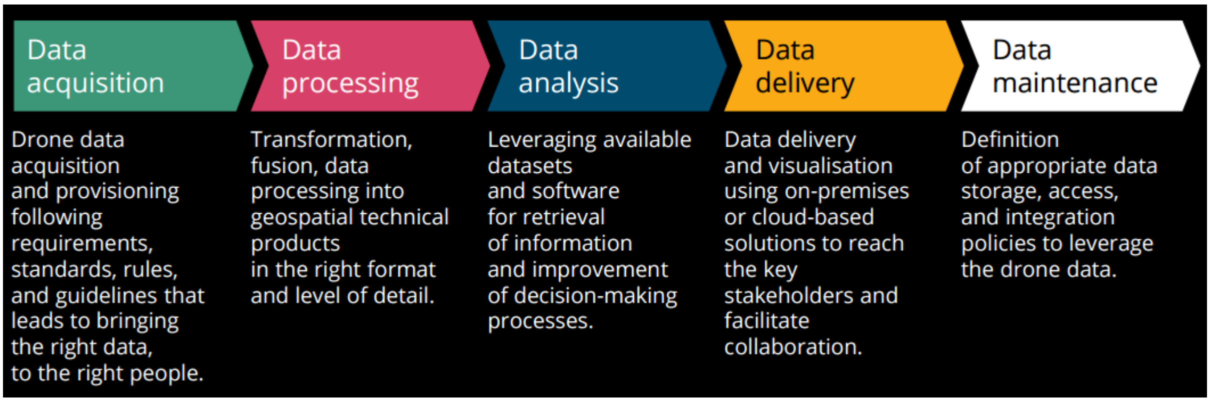


Figure 11: Drone data life cycle management.

Flying a drone over a construction site is the easiest part of the process. To fully utilise the benefits of the technology organisations must take care of the full data life cycle: it should be processed into 2D and 3D technical products, analysed, visualised, and properly stored. The quality of such data should be defined, standardised, and governed. Access to such data should be secured with the use of one of the cloud-based platforms that enable quick and effective online access to the data for all stakeholders.

Organisations that have failed to adopt such an approach often end up gathering terabytes of data on local hard drives. The datasets are too large and heavy to use effectively, except by a few qualified engineers or analysts that have access to heavy-duty workstations and are therefore not widely used by decision-makers. Such data is unreliable, because of a lack of consistent standards, which means overlaying on CAD files is not practical. Nevertheless, these organisations can still benefit significantly from the use of drone data. Land surveyors may use it for cut-and-fill analysis and other volumetric measurements, and decision-makers can watch videos captured over the construction site to get situational awareness. In such cases, the long-term benefits related to the use of drone data will not be fully utilised.

On the other hand, organisations that introduce a comprehensive approach to drone data lifecycle management are seeing long-term returns on investment. Such organisations gather data cyclically over their construction projects and use cloud-based software to process, store, and analyse the data, which has clear accuracy standards and metadata. They can overlay CAD and BIM projects on top of the data online, to analyse progress and identity delays or issues with adherence to design, which enables them to spot red flags early on and avoid future liabilities. The site is also well documented in case of any litigation issues.

Decisionmakers and all stakeholders would be able to use the data in relevant meetings to make decisions based on facts [25].

Human capital requirements	Regulatory requirements	User requirements
Impact on employees	Hardware requirements	Standardisation
Social impacts	Software requirements	IT infrastructure
Public acceptance	Data requirements	Operational model
Environmental impacts	Data governance	Costs and benefits
Safety impacts	Cyber security	Compliance to digital agenda

Figure 12: Drone digital transition dimensions.

Gathered data can be used to analyse the root cause of problems to avoid them in the future. The data can also be used to train AI models. Appropriate data management practices can help construction businesses break out of silos and facilitate cooperation between various business disciplines.

Organisations considering the implementation of drone technologies on a large scale must consider multiple factors: defining the skills required, analysing social and environmental impacts, meeting technology requirements, data governance and standardisation to operating model and more. The complexity of the challenge can sometimes stall progress in a company's digital transformation. However, global examples show that organisations which have successfully carried out this change management process are now experiencing significant benefits.

8.2. The adoption process

Most construction organisations that have successfully introduced drone technologies on a large scale went through a common path of gradual validation and implementation of the solution. The process typically starts with a Proof (or Proofs) of Concept (PoC) to demonstrate a particular technology and provide a feasibility study to evaluate its usefulness. It is typically done in an isolated environment on a selected construction project and focuses on validating a limited number of use cases, e.g., cut-and-fill or volumetric measurements. It is also a good opportunity for the team to get familiar with the technology, learn about regulatory requirements, test possibilities for integration of output data with software solutions used on a construction site, and experiment with presenting the results to key stakeholders. PoC's are conducted with minimal effort and budget. Organisations might test multiple use cases within a single PoC or perform multiple PoC's for each relevant use case before assessing the feasibility of the technology for their operations [26].

The output of a PoC project is also an initial business case that should give answers to key questions related to the choice of technology and operational model (e.g., in-house drone operations or a third-party subcontractor). Once the technology and selected use cases are validated and the business case is accepted, the next step in scaling drone technology is typically a pilot project. This aims at preparing the organisation for the implementation of a full production scale solution. While a PoC typically involves no more than a few drone flights, pilot projects may take several weeks or months and involve dozens of drone operations. Pilots require the engagement of a large number of stakeholders, as well as an initial investment in a subset of production solutions, including licensing and configuring software aimed at use in a final production environment at the construction site. The reasons for conducting a pilot project are to gain a better understanding of how the technology will be used in the field and to refine the model. During a pilot project, the team involved performs extensive validations of the ways in which drone data can be integrated into different processes and redesigns them when required.

The pilot project should identify the key barriers and challenges that need to be solved before full-scale implementation, e.g., integration with CAD and BIM, internet access at the construction site to access the data online, and upskilling requirements. The result should be a "Go" or "No-Go" decision on whether to further implement the solution as well as a clear definition of the implementation scenario and roll-out roadmap. Depending on the structure of the organisation, pilot projects can be deployed regionally, or even on individual construction sites. The production roll-out of the solution is a gradual process that may be phased into several years. In the construction sector, the organisations who are leading the field in terms of digital adoption are introducing the technology by building their own drone programs. They aim to create in-house centres of competence, responsible for promoting the technology and supporting particular construction sites in piloting and rolling out drone operations.

While the use and acceptance of the technology is gradually growing, and certain construction sites are starting to realise the benefits of the use of the technology, the further integration of drone data with other data sources and systems must be considered in order to realise the full potential of drone technology and data fusion. Very often, the introduction of drones is linked to the introduction of other digital technologies, such as BIM, or is part of a longer digital journey for the organization [26], [27].

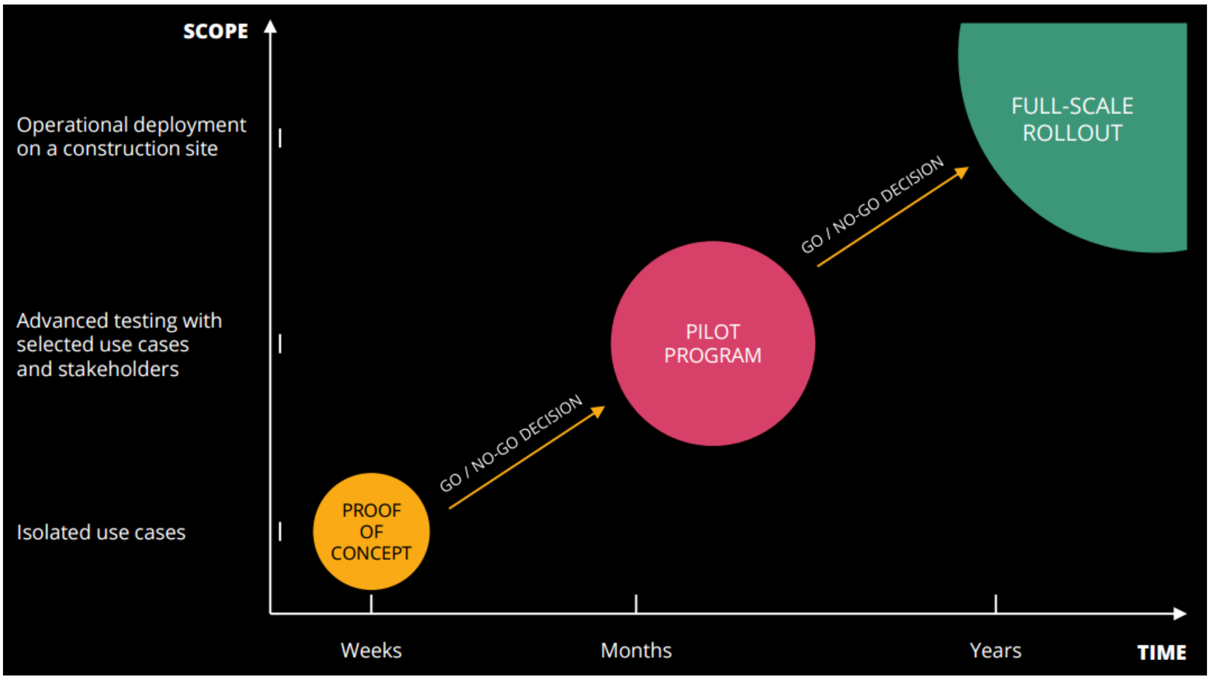


Figure 13: Recommended model for drone solution implementation.

8.3. Drone Data Integration in Construction Workflows

As it is explained in the previous sections, the effective use of drone systems in construction projects depends not only on data acquisition but on the structured integration of this data into existing project management and digital coordination environments. In order to provide actual operational value, drone outputs must align with established construction workflows, documentation standards, and stakeholder requirements.

Integration with BIM environments

Drone-generated datasets such as orthomosaics, point clouds, and 3D models are increasingly incorporated into Building Information Modelling (BIM) environments. These integrations support:

- Import of georeferenced point clouds into platforms such as Revit, ArchiCAD, and Tekla. These platforms are digital modelling environments used by architects and engineers to design, coordinate, and document building structures.
- Comparison of as-built conditions against design models.
- Detection of deviations or clashes between constructed elements and planned geometry.
- Progress validation against scheduled construction phases.

In renovation and retrofit contexts, reality capture based on drone data, often provides the baseline geometry that is required before design interventions are developed. To enable accurate model comparison, structured alignment between drone data and project coordinate systems is essential.

Integration with Construction Management Systems

Beyond BIM platforms, drone data is increasingly linked to construction management and collaboration software environments such as Procore, PlanGrid, and Autodesk Construction Cloud.

Typical integration workflows include:

- Upload of georeferenced site imagery to project dashboards.
- Linking drone-captured visuals to specific project milestones.
- Associating inspection findings with task management systems.
- Automated reporting to project managers and client representatives.

This integration supports transparency and improves communication between construction teams (on-site and off-site).

Reporting to stakeholders

Different project stakeholders require different types of drone outputs. For example:

- Architects and designers typically require BIM-compatible models or point cloud data.
- Structural engineers may require high-resolution geometric documentation.
- Project managers may prioritise progress imagery and comparison reports.
- Clients often require simplified visual summaries and structured documentation.

Quality assurance and review processes

Drone inspections must be incorporated into established quality assurance and quality control frameworks. This includes defining:

- When drone inspections are conducted within the project timeline.
- Who reviews and validates captured data.
- How detected issues are recorded and assigned and how corrective actions are tracked.

The integration of drone systems into construction workflows requires structured coordination across digital platforms, project governance systems, and stakeholder communication processes. When properly embedded into these workflows, drone operations move beyond isolated inspection tools and become part of standard project delivery and documentation practices.

8.4. Integration of drone technologies with existing digital tools used in construction

Integrating drones (UAVs) with BIM, digital twins, and site monitoring enables real-time construction automation by generating accurate 3D reality models, tracking progress, and identifying safety hazards. Drones enhance digital tools through rapid surveying and photogrammetry, directly feeding data into platforms for automatic comparison with as-built designs.

8.4.1. Key Integration Possibilities

- **Drone-BIM Integration** (As-Built vs. As-Planned): Drones generate 3D point clouds and mesh models that are overlayed on BIM models to check for construction deviations. This allows for automatic compliance checking of geometric design models against the actual site condition.

- **Digital Twin Synchronization**: Real-time drone data updates digital twin models, supporting predictive maintenance and active project management. This includes using RGB, LiDAR, and thermal cameras to monitor material delivery, equipment usage, and structural integrity.
- **Automated Site Monitoring**: Drones with AI can process data instantly, allowing for remote monitoring and identifying potential safety hazards and environmental impacts.
- **Geospatial Integration (GeoBIM)**: Drones integrate with GIS platforms to map large-scale infrastructure, offering precise geospatial data for urban planning and utility management.

8.4.2. Benefits in Construction

- **Improved Efficiency**: Practical integration would reduce the surveying time and boost productivity, which would enable faster and more frequent site inspections.
- **Cost Savings & Risk Mitigation**: Reduces manual work in dangerous areas, prevents costly rework, and enhances safety compliance.
- **Enhanced Collaboration**: High-resolution 3D models can be shared via cloud platforms (e.g., ArcGIS Online), enabling stakeholders to make faster, data-driven decisions.

8.5. Examples of moving from drone experimentation to operational deployment in construction

Moving from drone experimentation to operational deployment in construction requires transitioning from isolated, single-site pilot tests to standardized, company-wide workflows. Leading firms have achieved this by establishing internal FAA-certified teams, integrating aerial data with Building Information Modeling (BIM), and adopting automated "drone-in-a-box" technology.

Some practical examples from companies and guidance for this transition based on industry leaders are given below:

8.5.1. Shift from "Experiment" to "Standard Workflow"

Instead of using drones for occasional lively aerial photos, companies should integrate them into routine safety and progress tasks.

- **Weekly Documentation**: e.g. Brasfield & Gorrie moved from six drones in 2017 to over 38 in 2023, requiring weekly, standardized data capture across numerous sites, making it a "day-to-day" tool for project managers.
- **Standardized Checklists**: Implementation of mandatory pre-flight checklists that include safety audits, battery management, and airspace checks (using tools like B4UFLY) to ensure safety and consistency across different sites.

8.5.2. Integrate Drone Data with Existing Tech Stack

If drone data is only collected and accumulated, the operational deployment tasks would be unsuccessful, therefore it must be subsequently and regularly integrated into software the team or company already uses.

- **BIM and GIS Integration**: e.g. Brasfield & Gorrie uses Esri's Site Scan for ArcGIS to merge drone imagery directly into GIS maps, allowing teams to compare current work against design plans.
- **Virtual Collaboration**: e.g. Skanska USA uses drones for progress monitoring, feeding data directly into project management platforms for real-time analysis by stakeholders off-site.
- **AI-Powered Insights**: Using tools like OpenSpace Air, firms are automating the processing of imagery to detect discrepancies in as-built conditions versus the 3D model, providing automated updates on progress.

8.5.3. Move to Automated/Autonomous Operations

The wanted scale-up would be limited by the need for a licensed pilot at every site, therefore automated solutions would remove this bottleneck.

- **Drone-in-a-Box: Companies are** moving to "drone-in-a-box" solutions like Percepto or DJI Dock, which allow for autonomous launch, landing, and recharging on-site. These drones are programmed to perform daily, automated flights, reducing manual inspection labor by up to 70%.

- **Aerial-to-Ground Tech**: e.g. Komatsu integrates drone-captured data directly into autonomous bulldozers and excavators for automated, precise earthmoving.

8.5.4. Create an Internal Drone Program

Avoid relying on third-party vendors for routine work to reduce costs and increase speed.

- **In-House Training**: e.g. Hensel Phelps focused on safety, regulating its own use and investing in training to earn FAA waivers, enabling them to fly drones in areas where people are working.
- **Internal Certified Team:** Instead of temporary employees, a greater benefit would be to develop a group of internal employees who are certified by regulating organizations such as EASA, which would ensure consistent and high-quality data collection.

8.5.5. Start with High-Value, Low-Risk Use Cases

Instead of tackling complex tasks immediately, a greater benefit would be to build confidence by solving specific smaller weak points.

- **Stockpile Management**: Use of drone photogrammetry for accurate and fast inventory checks of materials, which would reduce the time spent on manual surveys.
- **Site Inspection & Safety**: Use drones to identify potential hazards on high-rise structures before workers ascend, reducing the need for dangerous manual inspections.

8.5.6. Summary of Best Practices for Scaling

Action	Description
Standardize	Create a repeatable process for every drone flight.
Centralize	Form an internal drone program team at corporate headquarters.
Automate	Use AI to detect issues and auto-generate reports.
Invest in Training	Get employees certified for compliance.
Use Quality Data	Capture raw images with high overlap (70-80%).

Necessary Skills, Certifications, and Training Pathways

9. Overview of the Necessary Skills, Certifications, and Training Pathways

The rapid adoption of Unmanned Aerial Vehicles (UAVs), commonly referred to as drones, across multiple sectors has transformed how data is collected, analysed, and applied. In industries such as construction, infrastructure inspection, agriculture, logistics, media, and public safety, drones have evolved from niche tools into integral components of digital and operational workflows. This transformation has generated a growing demand for professionals equipped with a comprehensive and multidisciplinary drone-related skill set.

This report provides an updated overview of the necessary skills required to effectively and responsibly use drones, drawing on the uploaded reference document and complementary industry resources. It further outlines the main types of certifications and training courses currently available, offering guidance for workforce development, vocational education and training (VET), and lifelong learning initiatives.

9.1. Overview of the Drone Skills Landscape

Modern drone professionals are no longer defined solely by their ability to pilot an aircraft. Employers increasingly seek multifaceted profiles that combine technical expertise, digital competence, regulatory awareness, and strong transversal (soft) skills. This reflects the growing complexity of drone operations, the value of data-driven outputs, and the need to operate safely within regulated airspace and sensitive environments.

The required skills can be grouped into four overarching core categories [24]:

- Technical and operational skills related to drone systems and flight.
- Digital skills related to data acquisition and processing together with analytical skills covering data interpretation, specifically in the construction context, and data integration into construction software and workflows.
- Regulatory knowledge, to understand when, where and how you can legally operate.
- Soft, managerial, and compliance-related skills that enable effective collaboration and responsible use.

- For successful organisation of the whole process that means it would be necessary to make:
- Drone data flow into cloud-based platforms (eg. Propeller Platform, Pix4D Cloud, DroneDeploy) [28]
- Platforms automatically process images to orthomosaics, point clouds, and 3D models.
- Data standardized with consistent metadata and known accuracy levels.
- Data accessible online to all stakeholders.
- Data overlaid on CAD (Computer-Aided Design or BIM models for immediate comparison.
- Historical data maintained for progress tracking.

9.2. Regulatory Complexity of the Training

As described previously, EASA has created a framework distinguishing between:

- Open Category: includes standard operations, low risk.
- Specific Category: includes operations requiring special authorization (BVLOS, altitude restrictions).
- Certified Category: includes high-risk operations requiring certification.

Construction projects often require Specific Category operations requiring risk assessment documentation, special approvals, insurance, and continuing compliance monitoring [29], [30].

From here a critical training implication can be inferred, which asserts that regulatory knowledge is non-negotiable, whereby drone-operators must understand which category applies to their mission or project and what documentation they need.

9.3. Core Technical and Operational Skills

9.3.1. Drone Flight and Aeronautical Knowledge

A solid understanding of flight principles and piloting techniques remains foundational. Key skills include:

- Understanding basic aerodynamics (lift, thrust, drag, weight).
- Manual and automated drone piloting.
- Use of stabilisation systems and GPS-assisted flight modes.
- Advanced piloting techniques (e.g. FPV, low-light or indoor operations).

- Emergency procedures and fail-safe management.
- Weather assessment and environmental awareness.

These skills ensure safe and predictable drone operation, particularly in complex or constrained environments such as construction sites or urban areas [31], [32], [33].

9.3.2. Electronics, Hardware, and Sensors

Drone platforms integrate multiple electronic and mechanical components. Professionals are expected to have practical knowledge of:

- Motors, electronic speed controllers (ESCs), and power systems.
- Flight control units and autopilot systems.
- Navigation sensors (GNSS, IMU, barometers).
- Camera systems and specialised payloads (thermal, multispectral, LiDAR).
- Basic assembly, maintenance, and troubleshooting.

This knowledge supports system reliability, reduces downtime, and enables informed payload selection based on mission objectives.

9.3.3. Software, Automation, and Programming

Software plays a critical role in both flight control and data exploitation. Relevant skills include:

- Use of ground control stations and mission planning software.
- Configuration of open-source or proprietary flight control firmware.
- Waypoint planning, geofencing, and autonomous missions.
- Basic programming skills (e.g. Python or C++) for automation and data processing.
- Familiarity with UAV software ecosystems and updates.

These skills allow professionals to customise missions, increase efficiency, and adapt drones to specific operational needs.

9.3.4. Advanced Technical Skills

In addition to core flight operations and standard payload management, drone professionals working in construction may be required to obtain more advanced technical competencies aligned with higher accuracy requirements and complex site environments.

These include:

- RTK/PPK setup and validation, including base station configuration, correction data verification, and accuracy assessment for survey outputs.
- LiDAR system operation and data processing workflows, including point cloud cleaning, classification, and georeferencing.
- Multi-sensor data acquisition, ensuring synchronization between RGB, thermal, and LiDAR datasets.
- Automated flight planning in complex 3D environments, particularly around façades, cranes, scaffolding, and confined urban sites.
- Indoor and GNSS-denied operational awareness, including use of vision-based positioning systems and safe flight planning in enclosed or partially enclosed spaces.
- Understanding Beyond Visual Line of Sight (BVLOS) operational requirements.
- Interpreting AI-generated inspection outputs.

9.4. Core Digital and Analytical Skills

9.4.1. Mission Planning and Data Capture

Effective drone use depends on careful mission design aligned with data requirements [31], [32], [33].

Key competencies include:

- Planning flight paths for optimal coverage and resolution.
- Matching sensors and payloads to use cases.
- Managing batteries, storage, and time constraints.
- Ensuring data consistency and repeatability.
- Understanding data quality requirements.

9.4.2. Data Processing and Analysis

Drones generate large volumes of data that must be transformed into actionable outputs. Required skills include:

- Photogrammetry and 3D reconstruction.
- Creation of orthomosaics, digital surface models, and point clouds.
- Use of specialised processing software and cloud platforms.
- GIS integration and spatial data analysis.

- Application of AI and machine learning for automated feature detection.
- Data visualisation and reporting.

Professionals who can convert raw drone data into insights provide significantly higher value to employers and clients.

9.4.3. Digital Literacy and Cybersecurity

As drone workflows become increasingly digital, broader digital competence is essential:

- Use of cloud-based collaboration platforms.
- Secure data storage and transfer.
- Cybersecurity basics: password management, VPN, phishing awareness.
- Data privacy: understanding GDPR implications when collecting images of private property [34].
- Awareness of cybersecurity risks.
- Compliance with data protection and privacy requirements.
- Collaboration platforms: sharing data with architects, engineers, site managers.

9.4.4. Integration of Drone Data into Construction Workflows

Beyond flight operation and data acquisition, construction professionals must develop the ability to integrate drone-generated data into existing construction management and engineering workflows. For example, construction professionals must understand how outputs derived from drone data, such as orthomosaics, 3D meshes and point clouds can be imported into BIM platforms (e.g., Autodesk Revit, ArchiCAD, Tekla Structures). Key integration competencies include:

- Importing georeferenced point clouds into BIM environments.
- Aligning drone data with project coordinate systems.
- Updating digital twin models with real-time data collected from construction sites.
- Detecting clashes between existing structures and planned renovations.
- Generate automated progress reports from drone data.
- Link visual documentation to project milestones.
- Organize data repositories for traceability.

In the construction context, drone competence should not be interpreted as aviation competence alone. It represents a subset of digital construction competence. The value generated by drone operations is directly proportional to the ability to integrate outputs into BIM, digital twins, cloud-based collaboration systems, and lifecycle asset management platforms. Therefore, training pathways must treat drone skills as embedded within broader digital construction transformation processes rather than as isolated technical abilities.

9.5. Core Regulatory, Safety, and Compliance Skills

Based on the literature review [31], [32], [33], [35], the following subcategories of skills have been identified:

9.5.1. European and National Regulations

- EASA drone regulations: three operational categories (Open, Specific, Certified)
- National regulation variations and local implementation differences
- Operator registration and remote pilot competency certification
- Risk assessment for demonstrating mission safety
- Standard Scenarios (STS-01/STS-02) application conditions.
- Understanding when a full Specific Operations Risk Assessment (SORA) is required.
- Conducting Specific Operations Risk Assessment (SORA).
- Coordination with local aviation authorities.
- Insurance requirements under national aviation frameworks.

9.5.2. Airspace Awareness

- Understanding airspace classifications: controlled vs. uncontrolled.
- No-fly zones: identifying and obtaining exemptions.
- U-space framework: emerging European air traffic management.
- Coordination with air traffic control.
- Interaction with U-space Service Providers (USSPs).
- Digital flight authorisation procedures.
- Remote Identification (Remote ID) requirements.
- Coordination with air traffic control (ATC) when operating near airports.

9.5.3. Safety and Risk Management

- Pre-flight inspections and identification of potential failure points.
- Emergency procedures.
- Site-specific hazards in construction environments.
- Personal protective equipment (PPE).
- First aid awareness.
- Incident reporting procedures and documentation.

9.5.4. Privacy and Legal Compliance

- Data protection (GDPR): capturing images of private property and individuals.
- Intellectual property: identifying who owns the generated drone data.
- Insurance: third-party liability and equipment coverage.
- Contracts: client requirements and obligations.

The presence of a strong regulatory competence is critical for commercial operations, but also for maintaining public trust in drone technologies, ensuring worker safety, and legally integrating drone technologies within construction environments. Regulatory literacy is increasingly becoming a core professional competency rather than a specialised add-on skill.

9.6. Core Soft Skills and Professional Competencies

Based on the literature review [31], [32], [33], the following subcategories of skills have been identified:

9.6.1. Communication

- Explaining drone capabilities and limitations to non-technical stakeholders.
- Discussing risk management with site management.
- Presenting data to decision-makers.
- Coordinating with other trades on site.
- Cloud-based data sharing.

9.6.2. Teamwork and Collaboration

- Construction is teamwork, drones integrate with surveyors, architects, site managers, safety officers.

- Integrating drone data with other data sources.
- Willingness to learn from colleagues.

9.6.3. Problem-Solving and Adaptability

- Adapting mission plans when conditions change.
- Troubleshooting skills.
- Creative thinking about new applications.

9.6.4. Project Planning and Documentation

- Managing schedules and timelines.
- Organizing data and maintaining accessibility.
- Documentation practices: weather conditions, sensor settings, mission parameters.

9.6.5. Leadership and Professional Development

- For senior operators: mentoring new team members.
- Continuous learning: drone technology evolves rapidly.
- Staying updated on regulatory changes.
- Risk assessment and liability evaluation.
- ROI calculation for digital investments.

These skills would enable professionals to operate effectively within complex organisational and project-based environments.

The required skills described above directly correspond to the five competence areas of the European Digital Competence Framework (DigComp 3.0), particularly:

- Information and Data Literacy (data interpretation, geospatial analysis).
- Communication and Collaboration (cloud-based data sharing).
- Digital Content Creation (generation of maps, 3D models, reports).
- Safety (cybersecurity, data protection, operational safety).
- Problem Solving (technical troubleshooting and adaptive workflow redesign).

9.7. Career Paths in the UAV Sector

Based on the literature review [32], [36], [37], the following subcategories of skills have been identified:

9.7.1. UAV Pilot and Flight Operations

A UAV pilot focuses on flight execution: manually operating drones or supervising automated missions. Common roles include:

- Aerial Photographer/Videographer: serving media, events, or cinematography.
- Inspection Specialist: conducting surveys of infrastructure, buildings, or agricultural fields.
- Delivery Pilot: engaging in logistics or medical supply transport (emerging field).
- Training Instructor: teaching new operators flight skills and regulatory compliance.

9.7.2. UAV Engineer or Technician

For specialty in hardware and software design:

- Mechanical/Electrical Engineer: designing drone frames, propulsion systems, or sensor mounts.
- Firmware Developer: coding flight control algorithms, implementing computer vision, or building secure communication protocols.
- Maintenance Technician: conducting repairs, firmware updates, and diagnostics on commercial drone fleets.

9.7.3. Data Analyst or GIS Specialist

With UAVs generating terabytes of data, for data-focused professionals' possible roles could be:

- Remote Sensing Expert: leveraging multispectral or thermal imaging for environmental studies, farming, or resource exploration.
- Machine Learning Researcher: building AI models that classify images, detect anomalies, or forecast patterns.
- GIS Specialist: integrating drone-derived data into mapping software to produce geospatial insights or interactive dashboards.

9.7.4. Project Manager or Consultant

With a focus in organisational oversight for UAV projects:

- Project Coordinator: aligning flight schedules, safety protocols, and team roles.
- Business Development/Consulting: advising clients on UAV strategy, compliance, or cost-benefit analysis for adopting drone solutions.
- Policy Liaison: working with local or national authorities to ensure project compliance and secure flight permissions.

9.7.5. Entrepreneur or Start-up Founder

Some professionals choose to found drone service companies, offering specialised flight operations, data analytics, or software platforms. This path requires an integrated blend of technical prowess, business acumen, marketing, and leadership to stand out in a competitive industry.

9.8. Certification structure

Aligning with European standards [38]:

- EQF Level 3 (Post-secondary): Basic operations, understanding foundations (40-60hours).
- EQF Level 4 (Advanced vocational): Specialized skills, independent practice (80-100hours).
- EQF Level 5 (Higher): Complex analysis, innovation, mentoring (120+ hours).

This ensures credentials are recognised across EU member states.

9.9. Types of Drone-Related Certifications

9.9.1. Regulatory and Operational Certifications

Depending on the country, common certifications:

- Basic and advanced drone pilot licences.
- Operator registration and competency certificates.
- Certificates for specific operational categories (e.g. A2, BVLOS).
- Safety and risk assessment qualifications.

These certifications are often mandatory for commercial drone operations.

9.9.2. Technical and Specialist Certifications

Optional but highly valued certifications:

- Aerial mapping and photogrammetry certification.
- Thermal imaging and inspection certification.
- GIS and remote sensing certifications.
- FPV or advanced flight skills certification.
- Maintenance and repair certifications.

9.9.3. Digital and Data Certifications

- Data analytics or GIS professional certificates.
- AI and machine learning certificates.
- Cybersecurity and data protection certifications.

9.10. Types of Training Courses Available

9.10.1. Formal Education and VET Programmes

- Vocational education and training (VET) courses in drone operation.
- Technical certificates in UAV systems or aerospace technologies.
- Higher education programmes in engineering, robotics, or geospatial sciences.

9.10.2. Short Courses and Modular Training

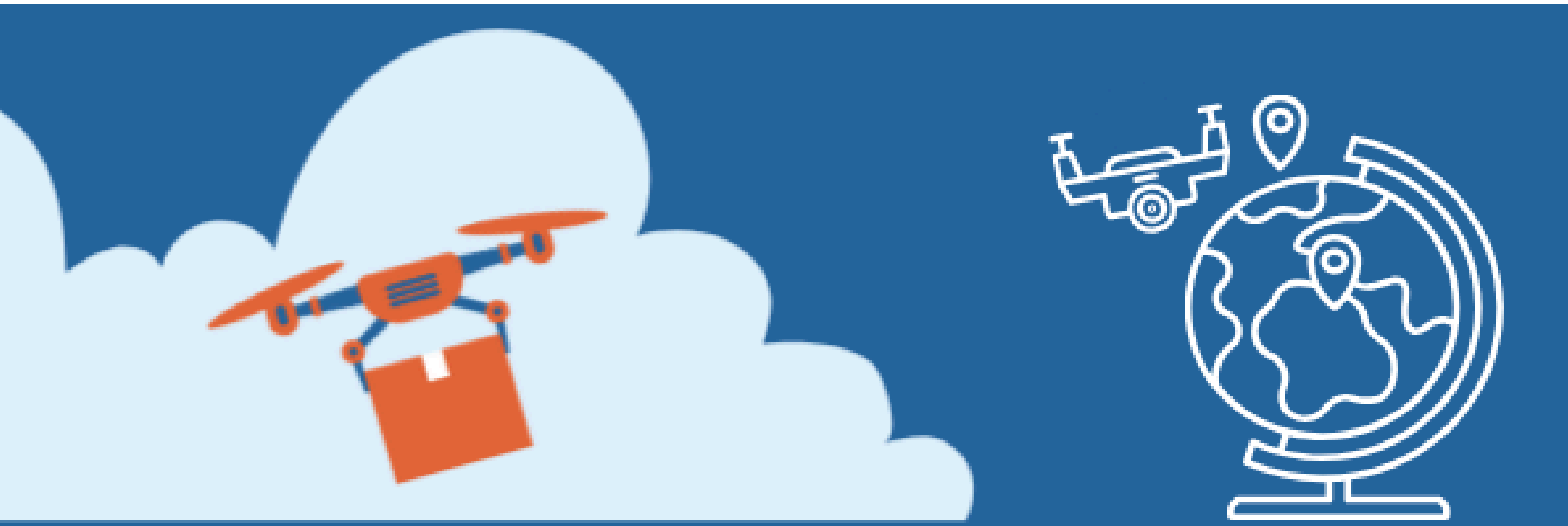
- Introductory and advanced drone piloting courses.
- Sector-specific courses (construction inspection, agriculture, media).
- Data processing and photogrammetry workshops.
- Regulatory and compliance training.

9.10.3. Online and Self-Paced Learning

- Online courses covering drone software, AI, and data analytics.
- Simulation-based flight training.
- Micro-credentials and digital badges.

9.10.4. Work-Based Learning and Informal Training

- Apprenticeships and on-the-job training.
- Industry placements and internships.
- Drone clubs, competitions, and community projects.



Insights from National Review on Drone use

10. Insights from National Review on Drone use

10.1. Status of drone use in North Macedonia

Drone use in North Macedonia's construction-related activities is emerging but still niche, concentrated in PV plants, industrial inspection and surveying rather than general building sites. Demand is growing in line with expansion of construction and PV projects, and a few organisations already use drones in a very mature way for monitoring, mapping and risk-reduction, while the wider market remains at an early adoption stage. The main constraints are limited data-processing and interpretation skills, partial understanding of regulations and operational limits, and the absence of construction-specific standards and structured training pathways focused on data and safety.

Labour Market and Emerging Roles

Drone-related roles exist but are still scarce. They typically appear embedded in positions such as surveyor, PV engineer or construction engineer rather than as standalone drone jobs. The main profiles are UAS drone operator, surveying/GIS engineer using drones, and PV plant inspection and maintenance engineer using drones.

Current Use Cases and Adoption Maturity

In practice, drones are used mainly for mapping, design, survey and monitoring of commercial PV power plants, and for inspection and monitoring of industrial and energy facilities such as fuel storage terminals and utility-scale PV plants. Within leading organisations (e.g. PV developers and industrial operators) adoption can be "very mature," but across construction more broadly drone use is still emerging and strongly focused on specific high-value, high-risk contexts.

Operational and Flight Skills

Many missions are flown using pre-programmed automatic flight plans, so basic equipment handling, mission setup and safety awareness are essential, while high-end manual piloting is needed mainly for exceptional or manual-flight situations. Critical operational skills include understanding equipment requirements and user manuals, planning missions and sensor use correctly, recognising weather and site hazards, and knowing when to abort or not initiate flights in poor conditions.

Technical Systems and Payloads

Interviewees underline the importance of understanding drone hardware and onboard systems, even though advanced automation can mask gaps in operator knowledge. Commonly used sensors include RGB cameras and thermal cameras for inspection and hotspot detection, plus standard onboard sensors (proximity, barometer, compass), while geofenced or restricted airspaces illustrate why operators must understand technical and legal system limits rather than relying solely on automation.

Data Acquisition and Interoperability

Drone data are processed through software platforms to create 3D models, inspection outputs and reports, with some operators reporting high expectations for processing skills and established internal workflows. In industrial and PV contexts, new thermal and visual data are routinely compared with previous inspections to detect anomalies (e.g. hotter PV modules or abnormal tank temperatures), and simple inspection reports feed directly into maintenance actions. However, the one-page national report notes sector-wide gaps in photogrammetry, GIS/BIM workflows and interpretation of thermal/inspection data, indicating that such good practice is not yet widespread.

Digital and Analytical Skills

Digital skills (software tools, processing platforms, IT knowledge) are considered "very important," and automated data processing is already common in some companies. The biggest gap is not piloting but data processing and interpretation: many professionals can fly a drone, but lack skills in thermal analysis, photogrammetry software, GIS tools, report preparation, and translating raw data into engineering or safety decisions.

Regulatory and Safety Framework

North Macedonia is aligning its unmanned aircraft framework with EU UAS rules, and a national MCAA licence or proficiency certificate is required for many commercial operations and heavier/faster drones. In practice, understanding of applicable regulations is generally low outside professional operators. The national framework is still perceived as basic, safety aspects are not fully covered, and risk assessments are rarely and individually carried out except by more professional actors, who focus largely on equipment protection.

Training and Competency Gaps

There is at least one certified national UAS training centre and emerging sectoral initiatives such as Drone4Build, but overall coverage of data/digital skills is only partial. Interviewed practitioners are not aware of robust, construction-specific training pathways. They highlight the absence of programmes addressing compliance and safety responsibilities, and call for official training authorities, obligatory exams and certification to raise standards.

Key Skill Gaps and Future Needs

Priority gaps identified include: data processing and interpretation (thermal analytics, photogrammetry, GIS/BIM workflows and reporting), understanding of regulations and operational limits, and risk-based safety procedures in real construction and industrial environments. Looking 3–5 years ahead, stakeholders emphasise IT-based knowledge (operational applications, software platforms), better training and education, and skills in flight planning and safety, photogrammetry/mapping software, and airspace rules, ideally within a standardised competency framework for construction-related drone roles.

Conclusions and Recommendations

In North Macedonia, drones already provide clear value in PV and industrial inspection by improving safety, enabling early risk detection and supporting targeted maintenance, but their use in mainstream construction remains limited and sparce. A national roadmap should prioritise integrated training pathways that combine basic piloting with advanced data workflows, thermal and photogrammetric analysis, GIS/BIM integration, and practical regulatory/safety modules, embedded in a standardised competency framework to raise professionalism and make drone operations safer, more reliable and better aligned with construction sector needs.

10.2. Status of drone use in Germany

In Germany, drones are already an established tool in construction, especially for surveying, inspections and documentation, with leading contractors such as Züblin, STRABAG and HOCHTIEF maintaining internal drone units. The national market counts around 400,000 drones in total (about 56,400 commercial) and roughly 15,000 UAV-sector employees, and construction demand is growing in step with this commercial expansion. At company level, some specialised firms (e.g. sewer and infrastructure service providers) report drones as firmly embedded in workflows for preliminary inspections and renovation planning, while advanced data processing is still often outsourced. The main challenges are a shortage of integrated profiles that combine piloting with data/BIM expertise and gaps in regulation and safety literacy, particularly around risk assessment and BVLOS operations.

Labour Market and Emerging Roles

Drone-related roles in construction are present and expanding, even if they are not yet separately coded in official labour statistics. Typical titles include UAV Surveyor/Data Analyst, Remote Pilot/Inspector, and BIM/GIS Specialist who process aerial data, and many site-manager or surveyor postings now mention experience with drones, 3D mapping or "Drohnenbefliegung" as a plus.

Current Use Cases and Adoption Maturity

Nationally, UAVs are actively used for topographic surveying, structural and infrastructure inspections, and site documentation, including for large contractors and network operators. At firm level, the interview with a sewer-service company shows drones are "already firmly established" for surveying and preliminary inspection of accessible sewer systems to plan subsequent inspection and renovation measures, with three in-house certified pilots (A1/A3 and A2). The main remaining gap there is internal capacity for advanced data processing rather than basic operational use.

Operational and Flight Skills

For open-air construction tasks, many operations are carried out in standard open-category scenarios (A2/A3) where line-of-sight flying and basic piloting competence are sufficient once proper mission planning and safety checks are in place. In specialised environments such as sewer pipes (diameter ≥ 1.5 m), however, utmost concentration, a steady hand and strict pre-flight routines (atmosphere measurement in the shaft, hardware test flights above ground) are essential to avoid incidents in confined spaces. Advanced operations like BVLOS are technically possible under the Specific category but are not yet used in the interviewed sewer company and remain rare in construction due to complexity of approvals.

Technical Systems and Payloads

German construction and infrastructure users employ a range of platforms, from standard survey UAVs to confined-space drones, for example, the interviewed firm uses an Elios 3 equipped with a high-resolution Ouster OS0-128 LiDAR sensor and a dedicated surveying payload. Operators in that context understand key system limitations (notably the 12-minute airtime limit) and maintenance requirements, but the national partner notes a broader market gap in professionals who can link platform capabilities with downstream data and BIM needs.

Data Acquisition and Interoperability

On the ground, drone data are used to generate point clouds and 3D models that support inspection, planning and renovation decisions. In the sewer example, raw flight data are converted into point clouds and then into 3D models. Nationally, common construction use cases require converting flight imagery into photogrammetric models, GIS layers and BIM-compatible outputs, yet many sites still rely on external service providers for photogrammetry and GIS work, reflecting incomplete in-house skills and workflows.

Digital and Analytical Skills

Digital skills are described as essential: data collection is only the first step, with correct interpretation and creation of accurate, measurable models seen as a separate and demanding competence area. In practice, many training offers and site teams still focus on manual inspection and basic documentation, while digital capabilities such as photogrammetry, GIS, 3D modelling and data analytics are often missing from standard construction VET and must be acquired via self-learning, consultants or specialist providers.

Regulatory and Safety Framework

Germany fully adopted the EU drone regulations (Delegated Regulation 2019/945 and Implementing Regulation 2019/947) on 1 January 2021, amending LuftVG and LuftVO so that EU-wide rules on Open/Special/Certified categories, pilot certificates, classes, registration and operational limits apply. Commercial construction pilots must hold an EU remote pilot certificate, typically A1/A3 for most drones and A2 for closer operations, with BVLOS and other higher-risk tasks falling under the Specific category and requiring SORA-based risk assessments and, where relevant, STS-02 approval. There are no construction-specific drone regulations, and instead all construction flights must follow general aviation law and restrictions (e.g. 21h LuftVO near residential or sensitive industrial zones), with BG BAU and DGUV providing advisory safety guidance for site use.

Training and Competency Gaps

Germany offers abundant generic UAV training through LBA-authorised exam centres (e.g. Droniq), vocational schools, chambers of commerce, private academies and university modules, and BG BAU runs workshops on drone safety. However, construction-focused curricula in formal VET remain sparse: traditional construction programmes rarely include UAV modules, and a BG BAU survey notes that existing training still centres on manual inspection while digital skills (photogrammetry, GIS, analytics) are largely absent. The interviewee from the sewer sector confirms that while piloting and basic system understanding are in place, in-house skills for advanced data processing and 3D modelling are missing and must currently be sourced externally.

Key Skill Gaps and Future Needs

Two overarching gaps are highlighted nationally: first, integrated technical profiles that combine UAV piloting with data analytics and BIM/GIS expertise, and second, stronger regulation and safety literacy (airspace law, BVLOS procedures, SORA-based risk management, and privacy). At company level, the sewer-service interview points specifically to future needs in photogrammetry and BIM integration, plus training priorities in data processing and modelling to turn raw point clouds into reliable engineering information. Together, these imply that in the next 3–5 years the most critical skills will be hybrid ones that bridge piloting, advanced data workflows and digital construction, rather than flying alone.

Conclusions and Recommendations

In Germany, drones are already delivering significant value in construction and infrastructure through safer, faster and richer surveys and inspections, and are firmly embedded in workflows in some specialist firms, but the wider sector still faces skills and training gaps that limit full exploitation of UAV-generated data. A national technology and skills roadmap should therefore focus on embedding UAV–digital modules into construction VET and continuing education (covering photogrammetry, GIS, BIM and data analytics), fostering partnerships between technical colleges and industry for practical projects, and publishing a joint "Construction Drone Handbook" from aviation and construction bodies to consolidate legal and safety best practice, while explicitly targeting the development of integrated UAV–data–BIM profiles in the labour market.

10.3. Status of drone use in Italy

Drone use in Italian construction is growing (around 23 percent increase in two years), especially in renovation, inspections and digital site monitoring, but is still only partially embedded in everyday workflows. Regulation and certification are mature and strict, while the main bottlenecks concern data-to-BIM integration, hybrid skills, and the practical complexity of operating safely in dense urban environments.

Labour Market and Emerging Roles

Recognised roles include UAS/Drone Pilot, Aerophotogrammetric Survey Technician, and BIM-UAV Coordinator, with demand clearly described as "growing." Many small and medium contractors still outsource these roles and use drones on a project-by-project basis rather than as an internal core capability.

Current Use Cases and Adoption Maturity

Drones are mainly used for roof and facade inspections, renovation documentation, storm-damage and insurance assessments, and general progress and safety monitoring. At sector level, adoption is rated as "partially integrated": some sites use drones routinely, but many firms deploy them only for complex or client-driven tasks.

Operational and Flight Skills

Construction sites require precise flying near scaffolding, cranes, power lines, traffic and people, so key skills are mission planning under ENAC/D-Flight constraints, manual control when automation is insufficient, and robust on-site risk assessment and emergency procedures. Coordination with the safety coordinator and site manager is essential, yet most existing training covers these aspects only generically.

Technical Systems and Payloads

Operators usually know how to use their equipment, but often lack deeper understanding of performance limits, calibration, accuracy and component lifecycles, which becomes critical when data feed into structural design or legal documentation. Optical cameras dominate, with thermography and LiDAR increasingly used for structural health and energy-efficiency assessments.

Data Acquisition and Interoperability

The main bottleneck lies not in collecting data but in turning it into actionable models: moving from images and point clouds to BIM and executable drawings is still not a standardised, linear process. PMIs often lack both software and skills, so advanced outputs remain under-used while photos and simple reports are more easily integrated.

Digital and Analytical Skills

Digital skills are needed across the chain—mission software, cloud platforms, photogrammetry, GIS and BIM—plus emerging AI tools for image classification and defect detection. In reality, many firms still work with shared folders, messaging apps and spreadsheets, making the jump to specialised platforms and analytics a significant step.

Regulatory and Safety Framework

Italy fully applies EU UAS Regulation 2019/947 via ENAC and D-Flight, professional construction operations almost always use EASA-compliant certifications (A1/A3, A2, STS-01/02) because of insurance and liability demands. However, obtaining permits in urban and restricted areas can take weeks and is perceived as complex and inconsistent, which undermines timely site use.

Training and Competency Gaps

ENAC-authorised centres provide solid generic pilot and regulation training, but coverage of data/digital skills is only partial and construction-specific content is limited. Practitioners see a gap in practical regulatory navigation for building sites, mission design based on technical needs, and packaging deliverables in formats that designers and contractors can immediately use.

Key Skill Gaps and Future Needs

Priority gaps are: Data-to-BIM interoperability, specialised sensor analysis (thermography, LiDAR), hybrid construction–drone profiles, stronger digital and AI competencies, and better understanding of ROI and business models for PMIs. Over the next 3–5 years, the emphasis is expected to shift from pure piloting toward these integrative, hybrid skills that connect drones with digital design and construction management.

Conclusions and Recommendations

For Italy, the focus should be on: making drone use more systematic on sites, simplifying and clarifying permitting for legitimate construction operations, and developing a national, construction-oriented competency framework and VET offer (e.g., a "Data-to-BIM" or "construction drone technician" certification) that bridges piloting, regulation, data processing and BIM/GIS integration.

10.4. Status of drone use in Spain

Drone use in Spain's construction sector is clearly growing, with around 150,000 registered operators by end-2025 and strong demand for drone pilots, surveying/mapping specialists and photogrammetry analysts. Adoption is fully embedded in some specialist firms but remains low to partial across much of the sector, with main bottlenecks in data analytics, BIM/GIS integration and hybrid skills that link piloting, engineering and digital construction.

Labour Market and Emerging Roles

The national input confirms that drone-related roles already exist in construction and that demand is "growing." Typical titles are Drone Pilot, Surveying and Mapping Specialist, and Photogrammetry Analyst, reflecting the importance of geospatial and monitoring services.

Current Use Cases and Adoption Maturity

Drones are used for site and road inspections, earthworks and mapping, construction monitoring, and inspections of roofs, facades and industrial/energy systems. Integration ranges from "fully integrated" in a specialist photogrammetry firm operating eight drones to low integration in more traditional organisations where drones are outsourced and seen as an additional, non-standard process.

Operational and Flight Skills

Construction tasks require precise piloting near roofs, facades, machinery and obstacles, as well as strong advance planning, risk management and response to wind, interference and signal loss. Automated missions cover many mapping tasks, but BVLOS operations in infrastructure are increasing, demanding higher competence in risk assessment and operational planning than generic pilot training usually provides.

Technical Systems and Payloads

Spanish operators commonly use RGB cameras and, in some cases, thermal cameras for inspections, with LiDAR and RTK systems emerging for high-accuracy 3D point-cloud surveys. Many pilots know how to operate the equipment but lack deeper understanding of accuracy, calibration and conditions that affect data quality, which is critical for engineering and certification uses.

Data Acquisition and Interoperability

Flights generate orthomosaics, 3D models, point clouds, visual inspection records and progress videos, with specialist firms running in-house photogrammetry departments and BIM-oriented reality capture workflows. However, in much of the sector data processing is handled by specialists, integration into standard construction workflows is limited, and drone work is still often perceived as a separate, add-on activity.

Digital and Analytical Skills

Digital skills—mission software, cloud platforms, photogrammetry, GIS and BIM—are considered essential, and some organisations already develop AI and big-data tools for image classification and incident detection. Yet many construction professionals have little experience integrating drone data into digital workflows, with gaps particularly around BIM methodology and connecting data to concrete analytical and management processes.

Regulatory and Safety Framework

Spain has implemented EU UAS rules nationally, certifications such as A1/A3, A1 and STS-EU are mandatory for professional use, though overall uptake is assessed as "medium." Practitioners report that regulations feel increasingly restrictive and bureaucratic, BVLOS flights are a major challenge, and permits for specific areas can take days or weeks, which strains construction schedules.

Training and Competency Gaps

Existing training programmes and certifications cover basic regulations and flight, but data/digital coverage is only "partial," and real-world construction applications and operator/permit management are weak points. There is a need to move from pilot-only training toward operational management skills and computer applications for processing captured data.

Key Skill Gaps and Future Needs

Priority gaps include data analytics and processing, BIM/GIS integration, hybrid profiles that combine safe piloting with construction knowledge and advanced processing, stronger regulatory/permit-management skills, and AI-related digital competencies. Over the next 3–5 years, hybrid skills—safe piloting, automation, advanced processing, BIM/GIS and AI—are expected to be decisive, with U-Space-related competencies also gaining importance.

Conclusions and Recommendations

In Spain, drones already deliver benefits in safety, speed and documentation, especially through specialist providers, but wider sector integration is held back by bureaucracy and skills gaps in data and construction-specific application. A national roadmap should prioritise specialised modules for data analytics and BIM/GIS integration, expand training beyond basic piloting to include operator and permit management, and foster hybrid construction–drone profiles, ideally within a standardised competency framework tailored to Spanish construction realities and EU rules.

10.5. Status of drone use in Greece

In Greece, drone use in construction is growing and moving from niche to partial integration, with major contractors such as TERNA SA already using drones systematically in many projects, especially during preliminary studies, planning and throughout the construction process. Labour-market roles like UAS operator, surveying drone specialist and photogrammetry technician are established, but the main bottlenecks concern processing drone-generated data, integrating outputs into BIM and other digital workflows, and raising overall digital maturity (including AI-supported analysis) across the workforce.

Labour Market and Emerging Roles

The national input confirms drone-related roles in construction, with demand explicitly described as growing. Key job titles include UAS operator (drone pilot), surveying drone specialist and photogrammetry technician, while in large organisations such as GEK TERNA Group these skills are embedded in surveying engineers and technical office teams rather than separated as standalone drone posts.

Current Use Cases and Adoption Maturity

At sector level, drones are used in construction but still treated as an emerging, expanding practice. Within TERNA SA, drones are used during preliminary studies, planning phases and across the construction process on many projects, with adoption characterised as “partially integrated” overall and close to fully embedded in some areas, although administrative management and permitting remain areas for improvement.

Operational and Flight Skills

Most construction-related missions in TERNA are flown as mainly automated operations, typically requiring A1/A3 certification in the open category. At national level, professional use in construction relies on A1/A3 and A2 for basic and urban operations, with STS-01/STS-02 and SORA-based operational authorisations used for more complex or BVLOS projects, implying the need for solid mission planning, risk assessment and regulatory understanding beyond basic stick-and-rudder skills.

Technical Systems and Payloads

Understanding drone hardware and onboard systems is considered very important for construction professionals, especially as organisations like TERNA commonly use photogrammetry cameras and LiDAR sensors. Operators there generally understand system limitations and maintenance requirements, but noticeable gaps remain in deeper technical and electrical details and in maintenance-related knowledge, which can affect reliability and lifecycle management of fleets.

Data Acquisition and Interoperability

In practice, Greek construction users primarily employ drone data to generate 3D models and related survey outputs for design and control purposes. Within TERNA, photogrammetry, GIS and BIM integration skills are available internally, with survey engineers and the technical office responsible for validating outputs before they enter standard workflows, whereas the national input notes wider sector gaps in data processing and integration into digital construction workflows.

Digital and Analytical Skills

Digital skills—software tools, cloud platforms and data-processing software—are rated "very important," and in TERNA digital integration is described as high, with AI-based tools used mainly at software level. Across Greece, however, coverage of data/digital skills in drone training is only partial, and both the one-pager and interview highlight missing capabilities in drone-generated data processing, precise alignment of outputs with project-specific requirements, and integration into BIM/GIS and broader digital construction analytics.

Regulatory and Safety Framework

Greece has fully implemented EASA Regulations 2019/947 and 2019/945 through the Hellenic Civil Aviation Authority, so EU UAS rules apply to all construction drone operations. Professionals in large firms feel fairly confident about regulations, but the most common challenge is delay in licensing and approvals from the aviation authority, risk assessments are not yet carried out systematically in all projects, and there are still no construction-specific guidelines beyond general aviation law.

Training and Competency Gaps

Drone training programmes exist nationally, yet their coverage of data and digital construction skills is only partial. TERNA's experience suggests current pathways are "quite effective" for basic operations and compliance, but interview feedback points to the need for micro-learning modules (short, frequent, targeted lessons), renewable certification schemes and a standardised skills framework to support continuous upskilling in data use and new technologies.

Key Skill Gaps and Future Needs

The Greek inputs converge on several priority gaps: drone-generated data processing and interpretation, integration of data into digital construction workflows (especially BIM), digital maturity and data utilisation (including AI), and adaptability and continuous learning in response to evolving platforms. Looking 3–5 years ahead, the most important skills are expected to be the ability to read, analyse and interpret data, combined with strong adaptability, so that operators and engineers can move from simply flying drones to exploiting their outputs in advanced, data-driven project delivery.

Conclusions and Recommendations

With the addition of the TERNA SA interview, the national picture for Greece shows drones already well embedded in leading contractors' workflows, but still unevenly integrated across the wider construction sector and digital value chain. To consolidate and scale this progress, Greece should develop structured training that couples UAS operational certification with photogrammetry, GIS, BIM and data-analytics skills, promote modular micro-learning and renewable certifications, and introduce a standardised competency framework that explicitly covers data interpretation, digital maturity and regulatory practice for drones in construction.

10.6. Identified Skills Gaps

Based on comprehensive analysis across 15+ documents reflecting the national status of use of drones in partner countries and the conducted interviews with construction professionals, drone service providers, VET educators, and industry stakeholders, the following critical skills gaps have been identified:

10.6.1. Domain 1: Operational and Flight Skills

Gap 1.1: Advanced Mission Planning and Risk Assessment

Current State: Most certified pilots (A1/A3) possess basic line-of-sight flying capability

Gap: Limited competence in mission planning under complex constraints, SORA-based risk assessment, and transition to Specific category operations

Evidence: Germany and Spain report operators can fly drones but struggle with authorization procedures for BVLOS, operations near people, or flights in controlled airspace

Impact: Inability to conduct advanced operations; over-reliance on external service providers for complex site missions

Gap 1.2: Regulatory Compliance and Safety Literacy

Current State: Certification covers regulatory framework at general level

Gap: Inadequate understanding of EU regulations in construction context (airspace restrictions, privacy, noise, proximity to structures); weak grasp of national variations and local procedures

Evidence: All countries report delays in obtaining permits; operators lack confidence in navigating authorization processes

Impact: Project delays; potential legal liability; under-utilization of technology due to perceived regulatory burden

Gap 1.3: System Knowledge and Performance Optimization

Current State: Operators know how to fly their assigned platform

Gap: Limited understanding of drone hardware limits, sensor specifications, environmental effects (wind, temperature, signal loss), battery management, maintenance cycles

Evidence: Greece notes gaps in technical/electrical details; Germany reports incomplete understanding of system limitations

Impact: Suboptimal equipment selection; unreliable data quality; equipment failures affecting site operations; inability to troubleshoot in field

10.6.2. Domain 2: Data Acquisition and Digital Processing

Gap 2.1: Photogrammetry and 3D Model Generation

Current State: External service providers handle photogrammetry; few internal operators have this skill

Gap: Operators cannot convert raw flight imagery into 3D models, point clouds, or orthomosaics; dependent on specialists or cloud services

Evidence: All countries report external outsourcing of photogrammetry; Italy and Spain note this as primary bottleneck

Impact: Extended project timelines; increased costs; inability to iterate data capture in field; delayed decision-making

Gap 2.2: GIS Integration and Geospatial Analysis

Current State: GIS expertise is typically specialized role, not part of construction workflow

Gap: Construction professionals lack skills in GIS platforms, coordinate system management, spatial analysis, and layer integration

Evidence: Germany, Italy, Greece report limited in-house GIS capability

Impact: Drone data not integrated with infrastructure mapping or site planning systems; geospatial context lost

Gap 2.3: Data Quality Assessment and Accuracy Validation

Current State: Limited understanding of what constitutes reliable data

Gap: Operators cannot assess whether captured data meets accuracy requirements for intended use (survey-grade vs. visual documentation); lack knowledge of RTK/PPK correction methodologies; unable to validate accuracy before data enters engineering workflows

Evidence: Spain and Italy report that regulatory requirements are not systematically applied

Impact: Poor decisions based on unreliable data; liability if data used for engineering design or legal documentation

Gap 2.4: Point Cloud Processing and LiDAR Data Analysis

Current State: LiDAR is emerging technology; few construction professionals have processing experience

Gap: Inability to process dense point clouds, manage file sizes, extract actionable information for building envelope assessment or detailed modeling

Evidence: Germany notes emerging need in sewer infrastructure; Spain and Greece have limited LiDAR processing expertise

Impact: LiDAR sensor potential in renovation/retrofit unrealized; expensive data captured but not analyzed

10.6.3. Domain 3: Building Information Modeling (BIM) and Digital Workflow Integration

Gap 3.1: Drone-BIM Integration and As-Built vs. As-Planned Comparison

Current State: Some BIM knowledge among engineers; limited understanding of how to incorporate drone data

Gap: Professionals cannot integrate point clouds/orthomosaics into BIM models; lack processes for automated comparison of drone-captured reality vs. design models; unable to identify deviations or construction errors

Evidence: All countries identify this as critical bottleneck; Italy and Spain emphasize data-to-BIM integration as primary gap

Impact: Missed opportunities for early defect detection; inability to systematically track construction progress against schedule; decision-making remains manual and visual rather than data-driven

Gap 3.2: Digital Twin and Lifecycle Management Integration

Current State: Digital twins are emerging concept; not yet standard in construction

Gap: No competence in linking drone data to digital twin environments; understanding of how continuous data feeds support asset lifecycle management, maintenance planning, renovation planning

Evidence: Greece notes need for digital maturity; emerging capability in advanced organizations but not sector-wide

Impact: Drone data does not contribute to long-term asset management; project-based rather than lifecycle value

Gap 3.3: Construction Management System Integration

Current State: Construction management platforms (Procore, PlanGrid, Autodesk Construction Cloud) are widely deployed; drone data integration is not standard

Gap: Limited understanding of how drone-captured imagery links into project management workflows; automated reporting and milestone tracking; document management

Evidence: Spain notes integration still emerging; many organizations work with shared folders and messaging apps rather than integrated platforms

Impact: Drone imagery remains disconnected from project management; value not fully realized in daily operations; stakeholder communication inefficient

10.6.4. Domain 4: Thermal Analysis and Building Energy Performance Assessment

Gap 4.1: Thermal Imaging Operation and Data Interpretation

Current State: Thermal cameras are available on many platforms; few operators have structured training

Gap: Inadequate understanding of thermal sensor operation, environmental factors affecting measurement accuracy (emissivity, time of day, weather), methodology for systematic building envelope assessment

Evidence: Germany identifies need for energy audits; Italy and Spain note thermal imaging as emerging but undertrained

Impact: Unreliable thermal data; poor decisions about retrofit priorities; energy efficiency assessment incomplete or inaccurate

Gap 4.2: Energy Audit Planning and Integration with EPC Processes

Current State: Energy Performance Certificates (EPC) are regulatory requirement; drone-based audits are emerging supplement

Gap: Missing competence in linking thermal drone surveys to EPC methodology, building codes, retrofit standards; inability to translate thermal findings into retrofit prioritization

Evidence: Energy efficiency audits identified as key renovation application but undertrained

Impact: Thermal data collected but not systematically integrated into renovation planning; disconnect between drone findings and retrofit execution

10.6.5. Domain 5: Regulatory, Safety, and Compliance Skills

Gap 5.1: SORA (Specific Operations Risk Assessment) Methodology and Application

Current State: SORA is formal requirement for Specific category operations; limited practical application in construction

Gap: Few construction professionals understand how to conduct SORA, identify Ground Risk Class and Air Risk Class, define mitigation strategies, and navigate authorization process

Evidence: All countries report SORA as complex barrier; inconsistent application across regions

Impact: Inability to conduct higher-risk operations independently; over-reliance on external risk assessment consultants; project delays waiting for authorizations

Gap 5.2: Standard Scenarios (STS-01, STS-02) Understanding and Application

Current State: Standard Scenarios simplify authorization for common operations; limited awareness in construction

Gap: Missing understanding of which construction operations fit within STS-01/STS-02; how to prepare documentation; what conditions must be met for streamlined authorization

Evidence: Emerging practice in Germany, Spain, Italy; not yet widely adopted

Impact: Unnecessarily complex authorization processes; failure to utilize simplified procedures available for routine construction operations

Gap 5.3: U-Space Coordination and Digital Airspace Integration

Current State: U-space is now operational in designated areas (Spain, Italy, France, Germany); limited construction workforce awareness

Gap: No understanding of U-space services, how to obtain digital flight authorizations, coordination with U-space Service Providers, remote identification requirements

Evidence: Emerging requirement in urban construction; virtually no training yet

Impact: Construction organizations unable to conduct urban drone operations as U-space becomes mandatory; unprepared for regulatory evolution

Gap 5.4: Privacy and Data Protection Compliance

Current State: GDPR is known requirement; limited application to construction drone data

Gap: Inadequate understanding of how to capture drone imagery without violating privacy; data retention and access controls; handling of personally identifiable information

Evidence: All countries mention privacy considerations; often overlooked in training

Impact: Legal exposure; potential project shutdowns due to privacy violations; stakeholder concerns about surveillance

10.6.6. Domain 6: Soft Skills and Professional Competencies

Gap 6.1: Project Planning and Workflow Integration

Current State: Construction professionals have project management training; limited linkage to drone operations

Gap: Inability to integrate drone flights into project schedule; coordinate timing with other site activities; plan data capture to support decision points

Evidence: Germany notes need for systematic integration into routines

Impact: Drone operations remain isolated from broader project flow; data captured does not align with decision-making timelines

Gap 6.2: Stakeholder Communication and Documentation

Current State: Documentation skills present in construction; limited application to drone data presentation

Gap: Inability to translate drone data into stakeholder-appropriate formats; communicate findings to architects, engineers, managers, clients; create defensible documentation for legal or compliance purposes

Evidence: All countries note need for better packaging of outputs

Impact: Drone insights not effectively communicated; decision-makers receive raw data rather than actionable intelligence

Gap 6.3: Business Case Development and ROI Analysis

Current State: Business professionals have ROI training; lacking in construction drone context

Gap: Inability to calculate return on investment for drone programs; justify equipment and training costs; develop business cases for scaling operations

Evidence: Spain notes ROI and business models poorly understood by project managers

Impact: Difficulty justifying investment in drone programs; scaling stalls due to unclear value proposition

Gap 6.4: Adaptability and Continuous Learning Mindset

Current State: Technology landscape changing rapidly; training often static

Gap: Limited culture of continuous upskilling; inability to quickly learn new platforms, sensors, or software; resistance to emerging technologies (AI, autonomous systems)

Evidence: Greece notes need for adaptability and renewable certification schemes

Impact: Skills become outdated quickly; organizations unable to leverage emerging technologies; competitive disadvantage

Conclusions: National Status of Drone Use and Skills Needs

11. Conclusions: National Status of Drone Use and Skills Needs

11.1. Findings on National Status

11.1.1. Sector-Wide Adoption Pattern

Across the European construction industry, drone adoption follows a clear progression from experimental pilots to operational integration. The report documents that drone use has grown 23-50% in recent years across major EU markets (Germany, Italy, Spain, Greece), with clear application demand in renovation, inspections, and digital site monitoring. However, adoption remains uneven: some specialist firms have fully embedded drone operations into daily workflows, while traditional construction organizations continue to deploy drones primarily for isolated, client-driven projects.

11.1.2. Primary Construction Applications

The evidence demonstrates that drones are now deployed across the full construction lifecycle:

- **Surveying and Mapping:** High-resolution orthomosaics, 3D terrain models, and topographic surveys enable accurate site planning and earthwork calculations
- **Progress Monitoring:** Systematic documentation enables real-time schedule adherence assessment and stakeholder communication
- **Façade and Building Envelope Assessment:** Critical for renovation and retrofit projects, where thermal imaging and photogrammetry detect deterioration, thermal bridges, and structural defects
- **Safety Inspections:** Aerial perspective reduces need for high-risk manual inspections in scaffolding, high structures, and hazardous zones
- **Equipment and Asset Tracking:** Optimization of resource management on large sites
- **Quality Control and Compliance:** Early defect detection prevents costly rework
- **Infrastructure and Building Envelope Diagnostics:** Particularly relevant for energy efficiency audits and pre-renovation assessment

11.1.3. Technology Maturity and Regulatory Readiness

The construction industry now has access to mature, proven drone platforms: multirotor systems (quadcopters, hexacopters) for precision work, fixed-wing systems for large-area coverage, hybrid VTOL platforms for versatility, and emerging autonomous solutions (drone-in-a-box, swarm systems). Regulatory frameworks have reached operational maturity, with EU-harmonized rules (EASA 2019/945, 2019/947) now in practical deployment across all member states. U-space airspace management has transitioned from planning to active deployment in designated urban and controlled environments in Spain, Italy, France, and Germany, enabling digitally managed, conflict-free drone operations.

11.2. Critical Skills and Competency Gaps

Evidence from multi-country research reveals five key domains of skills gaps:

11.2.1. Operational and Flight Skills

- **Gap:** Many operators possess basic piloting competence (A1/A3 certification) but lack deeper understanding of mission planning, SORA-based risk assessment, and Standard Scenarios procedures
- **Impact:** Difficulty in transitioning from simple visual flights to Specific category operations (BVLOS, operations near people, flights in controlled airspace)
- **Need:** Advanced training in risk management, operational authorization procedures, and regulatory compliance

11.2.2. Technical and Sensor Knowledge

- **Gap:** Operators understand how to fly their equipment but often lack depth in performance characteristics, sensor calibration, accuracy limitations, and component lifecycle management
- **Impact:** Poor decisions about equipment selection, incorrect sensor usage, unreliable data quality affecting downstream engineering decisions
- **Need:** Structured technical training on drone platforms, payloads, sensors (RGB, thermal, LiDAR), and their performance in construction contexts

11.2.3. Data Processing and Digital Integration

- **Gap:** Most critical bottleneck—the skills gap between data acquisition (flights) and actionable outputs (BIM-integrated models, decision-ready reports). Many organizations accumulate terabytes of unusable local data; external service providers handle photogrammetry, GIS work, and 3D modelling

- **Impact:** Full potential of drone data remains unrealized; ROI is limited to simple visual documentation rather than systematic decision-making
- **Need:** Training in photogrammetry software, GIS platforms, point-cloud processing, 3D model creation, and integration into BIM/construction management systems

11.2.4. BIM and Digital Workflow Integration

- **Gap:** Construction professionals lack understanding of how drone-generated data (orthomosaics, point clouds, mesh models) integrate into BIM environments (Revit, ArchiCAD, Tekla), digital twins, and construction management platforms (Procore, PlanGrid)
- **Impact:** Drone data operates in isolated silos; comparison of as-built vs. as-planned conditions, automated compliance checking, and stakeholder collaboration remain manual and inefficient
- **Need:** Training combining BIM methodology, data interoperability standards, GeoBIM workflows, and practical integration exercises

11.2.5. Business, Organizational, and Hybrid Skills

- **Gap:** Shortage of integrated professionals who combine safe piloting, regulatory knowledge, data expertise, and construction domain understanding. Organizations struggle with business case development, ROI assessment, and operational model decisions (in-house vs. outsourced)
- **Impact:** Failure to scale drone programs beyond isolated pilots; difficulty in managing technology transition within organizations
- **Need:** Training in project management, business case analysis, data lifecycle governance, organizational change management, and construction-specific applications

11.3. Workforce Development Requirements (2026-2030)

To close the identified gaps and enable the transition from Phase 1 (operational adoption) to Phase 2 (integrated digital workflows), the construction sector will require:

11.3.1. Immediate Priority (2025-2026)

- 15,000+ additional trained professionals across Europe in hybrid drone-data-BIM roles
- Standardized curriculum for construction drone technicians covering piloting, data acquisition, and basic processing
- SORA and Standard Scenarios training for Specific category operations

11.3.2. Medium-Term Priority (2026-2030)

- 30,000+ professionals with advanced digital skills in photogrammetry, GIS, and BIM integration
- In-house competency centers in construction organizations for continuous upskilling
- Formalized apprenticeship pathways combining flight training with construction apprenticeships
- AI and emerging technology training for next-generation operators

11.3.3. Long-Term Strategy (2030-2035)

- Integration of drone-digital competencies into all construction technician and engineer training
- Lifelong learning pathways for continuous adaptation to emerging platforms and technologies
- Advanced specializations (autonomous operations, drone swarms, digital twin management)
- Regulatory updates and compliance training cycles aligned with EASA and U-space evolution

12 Conclusion

The evidence is clear: drones are no longer emerging technology in European construction. They are becoming standard operational tools, with proven applications, mature regulatory frameworks, and growing commercial adoption. However, this technological readiness is not matched by workforce readiness. The critical constraint to broader, more effective drone deployment is not technology, but competence.

Current VET systems have adequately prepared construction professionals for traditional tasks but are inadequately structured for the integrated, data-driven, digitally-enabled construction practices that drone technology enables and demands. Construction organizations that successfully scale drone operations have created hybrid competency profiles—combining piloting, regulatory knowledge, technical system understanding, and advanced digital skills—that are not yet standardized in formal training pathways.

The next 3-5 years are pivotal. Organizations that invest in structured, comprehensive training programs bridging piloting, data processing, and construction integration will gain competitive advantage. Those that continue with isolated pilots or generic pilot training will be constrained by the very skills gaps documented in this report. The construction industry must transition from treating drones as specialized equipment operated by external experts to embedding drone competencies—particularly in data integration and digital workflows—into the core skill sets of construction professionals.

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Glossary

Abbreviation	Full Form
5G	5G (5th Generation mobile networks)
AI	Artificial Intelligence
AMC	Acceptable Means of Compliance
ANAFI	ANAFI USA (drone model name)
ARC	Air Risk Class
ATC	Air Traffic Control
ATM	Air Traffic Management
BAE	British Aerospace
BIM	Building Information Modelling
BMS	Battery Management System
BVLOS	Beyond Visual Line of Sight
CAD	Computer-Aided Design
CMOS	Complementary Metal-Oxide-Semiconductor
DEM	Digital Elevation Model
DJI	Dà-Jiāng Innovations
EACEA	Education, Audiovisual and Culture Executive Agency
EASA	European Union Aviation Safety Agency
EC	European Commission
EPC	Energy Performance Certificate
EQF	European Qualifications Framework
ESC	Electronic Speed Controller
ESCO	European Skills, Competences, Qualifications and Occupations
EU	European Union
eVTOL	Electric Vertical Take-Off and Landing
FCS	Flight Control System
FPV	First-Person View
GDPR	General Data Protection Regulation7
GIS	Geographic Information System (or Spatial Information System)
GM	Guidance Material
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRC	Ground Risk Class
HDR	High Dynamic Range
HVAC	Heating, Ventilation, and Air Conditioning

>_abstract IT Experience Experience it
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HELLENIC DRONES
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IAM	Innovative Air Mobility
IEC	International Electrotechnical Commission
IMU	Inertial Measurement Unit
ISO	International Organization for Standardization
ISR	Intelligence, Surveillance and Reconnaissance
ITcon	International Journal of Construction (ITcon)
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
JU	Joint Undertaking
LiDAR	Light Detection and Ranging
MCU	Microcontroller Unit
MEP	Mechanical, Electrical & Plumbing
MP	Megapixel
MQ-9	MQ-9 Reaper
OSHA	Occupational Safety and Health (Administration/Act)
PDB	Power Distribution Board
PoC	Proof of Concept
PPE	Personal Protective Equipment
PPK	Post-Processed Kinematic
ROI	Return on Investment
RQ-4	RQ-4 Global Hawk
RTK	Real-Time Kinematic
SESAR	Single European Sky ATM Research
SLAM	Simultaneous Localization and Mapping
SORA	Specific Operations Risk Assessment
STS	Standard Scenario
SWOT	Strengths, Weaknesses, Opportunities, Threats
UAM	Urban Air Mobility
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
US	United States
USA	United States of America
USSP	U-space Service Provider
VET	Vocational Education and Training
VPN	Virtual Private Network
VTOL	Vertical Take-Off and Landing

Annex 1

1-Page National Partner Input - Drones in Construction

Partner organisation:

Country:

Contact person:

Date:

Labour Market & Employment

- Drone-related roles in construction present? (Yes/No):
- Demand trend (Growing/Stable/Limited):
- Main job titles (max 3):

Certifications

- Mandatory drone certifications for construction? (Yes/No):
- Main certifications used (e.g. A1/A3, A2, BVLOS):
- Estimated uptake (High/Medium/Low):

Job Postings Evidence

- Evidence of drone skills in job ads? (Yes/No):
- Most requested skills (tick or list):
- ☐ Drone operation ☐ Data processing ☐ BIM/GIS ☐ Regulation

Regulation & Standards

- EU UAS regulation implemented nationally? (Yes/No):
- Construction-specific guidelines available? (Yes/No):

Training & Skills

- Existing drone training programmes? (Yes/No):
- Coverage of data/digital skills (Adequate/Partial/Missing):

Key Insights

- Top 2 skill gaps identified:
- One key recommendation for the Technology Roadmap:

Annex 2

Semi-Structured Interview for Drone Professionals

Name and surname:

Organization Name:

Place & Date:

Dear Interviewee,

Thank you for sharing your valuable knowledge and experience on drone use. Please give your inputs by answering at least 1 question per group, selected by your choice.

1. Background & Role Context

1. Can you briefly describe your role and experience with drones in the construction sector? 2. In which types of construction activities do you most frequently use drones (e.g. inspection, renovation, monitoring)? 3. How mature would you say drone adoption is within your organization or projects?	Insert your answer here (only one question from this group)

2. Drone Operation & Flight Skills

Validation focus: Are operational skills adequately covered by existing training?

4. What level of drone piloting skills are typically required for construction-related tasks in your experience? 5. Which operational skills are most critical on construction or renovation sites? 6. How prepared are operators to handle unexpected situations (weather changes, signal loss, obstacles)? 7. Are advanced operations (e.g. BVLOS, automated missions) currently used or planned in your projects?	Insert your answer here (only one question from this group)

3. Technical & Systems Knowledge

Validation focus: Depth of technical knowledge vs. real operational needs

8. How important is understanding drone hardware and onboard systems for construction professionals? 9. Which sensors or payloads are most commonly used in your work? 10. Do operators typically understand system limitations and maintenance requirements? 11. 11. Where do you see the biggest technical knowledge gaps among drone professionals?	Insert your answer here (only one question from this group)

4. Data Acquisition & Processing Skills

Validation focus: Gap between data collection and data exploitation

12. How is drone data used after flights (e.g. 3D models, inspections, reports)? 13. What level of data processing skills is expected from drone operators today? 14. Are photogrammetry, GIS, or BIM integration skills sufficiently available in your organization? 15. What challenges do you face in ensuring data quality and reliability?	Insert your answer here (only one question from this group)

5. Digital & Analytical Skills

Validation focus: Digital literacy and advanced analytics readiness

16. How important are digital skills (software tools, cloud platforms) for drone-related work? 17. Are AI-based tools or automated analysis currently used? 18. How well do professionals integrate drone data into digital construction workflows? 19. What digital skills are most lacking among current professionals?	Insert your answer here (only one question from this group)

6. Regulatory, Safety & Compliance

Validation focus: Regulatory knowledge vs. operational reality

20. How confident are drone professionals in understanding applicable regulations? 21. What regulatory or safety challenges do you encounter most frequently? 22. Are risk assessments (e.g. operational or site-related) carried out systematically? 23. Do current training programs adequately address compliance and safety responsibilities?	Insert your answer here (only one question from this group)

7. Construction-Specific Application Skills

Validation focus: Sector-specific relevance of drone skills

24. How well do drone operators understand construction and renovation processes? 25. Are drone outputs aligned with the needs of engineers, architects, or site managers? 26. What construction-specific knowledge is essential but often missing? 27. How can drone skills better support renovation and retrofitting projects?	

8. Skills Gaps & Future Needs

28. Which skills will become most important in the next 3–5 years? 29. Where do you see the largest gaps between current skills and future needs? 30. Which skills should be prioritized in training programs? 31. What role should trainers and educators play in closing these gaps?	Insert your answer here (only one question from this group)

9. Training & Validation

32. How effective are current training pathways for drone professionals? 33. What improvements would you suggest for future drone training programs? 34. How should competencies be assessed and validated? 35. Would a standardized competency framework be useful for your sector?	Insert your answer here (only one question from this group)

Annex 3

The potential benefits of the use of drones in construction

PHASE	ACTIONS	DRONE INVOLVEMENT	DRONE PRODUCTS	APPLICABILITY OF UAS TECHNOLOGY	POTENTIAL IMPACT ON PROCESS EFFICIENCY
PRE-CONSTRUCTION					
PLANNING AND DESIGN	**Project concept**	-	×	×	×
	Project design	Generating high resolution maps to better align the project with environmental conditions.	Orthophoto DSM 3D model		
LAND PURCHASE	**Validation of land coordinates**	The use of drones serves to verify plot boundaries, especially in countries where accurate records are lacking.	Orthophoto		
	Verification of suitability for project concept	UAVs may help to spot issues, which might not be seen from ground level or in available documentation.	Orthophoto 3D model		
BUILDING PERMITS	**Securing all required permits**	-	×	×	×
PREPARATION FOR CONSTRUCTION	**Calculating demand for materials**	Estimation of earthworks and other operations related to preparation of the site for construction and subsequent usage.	DSM 3D model		
	Estimating schedule of work	-			
	Procurement and assembling workforce	Part of the operations can be augmented by drones, which allows a reduction in the number of workers needed for measuring and inspection tasks.	×		

PHASE	ACTIONS	DRONE INVOLVEMENT	DRONE PRODUCTS	APPLICABILITY OF UAS TECHNOLOGY	POTENTIAL IMPACT ON PROCESS EFFICIENCY
CONSTRUCTION					
PROGRESS MONITORING	**Earthwork stage**	Precise earthwork volume calculations, preparing accurate data for machine steering systems. Verification that works are carried out to plan and in accordance with the schedule.	DSM Orthophoto 3D model		
	Construction works	Detection of errors and comparing photogrammetry output with digital project plans. Verification that works are carried out to plan and in accordance with the schedule.	Orthophoto 3D model		
	Finishing works	Detection of errors and comparing photogrammetry output with digital project plans. Verification that works are carried out to plan and in accordance with the schedule.	Orthophoto 3D model		
	Payment release	Compilation of detailed documentation of the work status in the form of standard drone footage and photogrammetric products, for payment settling acceleration with the contractors.	Orthophoto 3D model Video & photo		
SAFETY & SURVEILLANCE	**Locating hazards on site**	3D overview of the site from UAS enables identification of higher-risk areas, allowing countermeasures to be put in place.	Video & photo 3D model		
	Monitoring workers' compliance with safety standards	Drones can identify workers breaking safety standards—the mere use of technology to pursue enforcement is enough of a deterrent/encouragement for most.	Video & photo		

PHASE	ACTIONS	DRONE INVOLVEMENT	DRONE PRODUCTS	APPLICABILITY OF UAS TECHNOLOGY	POTENTIAL IMPACT ON PROCESS EFFICIENCY
POST-CONSTRUCTION					
MAINTENANCE	**Structure inspections**	Providing detailed geometric, visual and structural condition information for numerous objects – which is especially useful in hard-to-reach places.	Point cloud 3D model Video & photo		
	Preparation of site for use	Verification that auxiliary infrastructure is located in accordance to plans. Aiding restoration of surrounding area to pre-construction condition.	Orthophoto 3D model		
CONSTRUCTION HANDOVER					
TECHNICAL CONDITIONS	**Preparation of as-built documentation**	Providing detailed geometric and visual data for the purpose of drawing up technical and legal documentation.	Point cloud 3D model Video & photo		
LEGAL CONDITIONS	**Verification of the project's adherence to legal requirements**	-	×	×	×

DRONE4BUILD

Elevating the knowledge of construction professionals on the use of drones in construction

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