DRONES

IN CONSTRUCTION

Unpacking the value that drone technologies bring to the construction sector across Latin America

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The team consisted of the following people:

Smeldy Ramirez Rufino, Senior Private Sector Development Specialist, IDB Lab

Manuel Rodriguez Porcel, Senior Transport Specialist, Inter-American Development Bank

Orlando Perez Richiez, Executive Director, Centro de Innovación de Drones at the Parque Cibernético de Santo Domingo

Jorge Seré, Director, PwC Capital Projects & Infrastructure

Aleksander Buczkowski, Director, PwC Drone Powered Solutions

Matilde Morales, Manager, PwC Capital Projects & Infrastructure

Kamil Bieniek, Technical Consultant, PwC Drone Powered Solutions

We are grateful for the collaboration of Alexander Riobo, Cesar Buenadicha Sanchez, Isabel Granada, Jesus Tejeda, Luben Petkoff, Martin Duhart, Mauricio Bayona, Monica Takako Otsuka, Rapha Dewez, and Ruben Doboin.

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Key Findings

Key Finding 1: Although still at low levels, there has been a gradual adoption of drones in construction.

Several industries have already implemented drones in their daily operations, and the technology is reaching high levels of readiness and maturity. The construction sector is not an exception.

Although at a slower pace, UAV (Unmanned Aerial Vehicle) technology is beginning to play a role across the entire lifecycle of capital projects and has even filtered down to small and medium size infrastructure projects. Specifically, within supervision activities, drones can help with precise earthwork volume calculations, preparing accurate data for machine steering systems, verification that works are carried out to plan and in accordance with a schedule, detection of errors, and the identification of higher-risk areas, among other activities.

Compared to other construction technologies, drones are relatively easy to pilot. In addition, professional drone services are widely available across Latin American and Caribbean countries, and the barriers to entry in terms of purchasing drone hardware and software is also low.

Key Finding 2: Using drones in supervision has various quantitative and qualitative benefits.

Typical problems faced in the construction sector across Latin America (such as project delays and cost overruns, personnel shortages, safety, and litigation) have been addressed with drones, showing beneficial results.

According to the PwC survey developed for this report, an average of 6-7 out of 10 respondents state that using drones shortened the project schedule and reduced cost by at least 10%. Other benefits mentioned included improved information quality and greater objectivity, better management processes and decision-making, increased productivity, reduction in the number of errors or their early detection, worker safety, improved evidence against litigation, and care for the environment, among others.

The practical benefits depend primarily on the type of project. For example, for large linear infrastructure construction projects, such as roads, the advantage lies in improved project management and a more precise overview of the status of the work being completed. On the other hand, supervising the construction of multi-story buildings in confined urban spaces can result in increased staff safety.

Finally, it is worth mentioning that there are cases in which the activity could not have been carried out in any other way, either due to difficulties in accessing the area (due to vegetation, for example) or by the speed with which the development of the activity was required.

Key Finding 3: There are still several barriers to drone adoption that should be addressed.

Although there is generally a high level of satisfaction with UAS technology, the adoption and the maturity of use cases is still at an early stage, especially among small and medium companies. From a technical point of view, drone hardware and software are ready for broader and more complex use cases. However, some obstacles remain unsolved.

One is legislation, which in many countries is still at an early stage of maturity and does not allow beyond-visual-line-of-sight (BVLOS) operations. It is often difficult to obtain the necessary permissions and flight authorisations, and sometimes the relevant procedures are lacking entirely.

The difficulty in calculating the financial benefits and savings of using drones in construction projects is probably an additional factor that slows down the adoption of drone technology among stakeholders in the industry. Most companies that have used UAS technology could not quantify the reduction in time, necessary personnel, or even more qualitative aspects, which means that the benefits could be underestimated.

Until broader steps are taken in all these areas, the full potential of the technology will not be unleashed. It should also be noticed that, in some cases, firms that carry out supervision activities in the construction sector do not use drone technology because the other stakeholders (e.g., the government) do not either. In other words, the incentives to implement this technology would be more significant if other parties were at a higher level of adoption, or if the example of implementation would come from the top.

1.

Introduction

There has been rapid adoption of drone technologies around the world for a vast number of commercial applications. Over the past several years, hundreds of thousands of drones were deployed in the workforce with use cases focused on mapping, industrial inspections, surveillance, and, more recently, package delivery.

Several industries have already implemented drones in their daily operations, and the technology is reaching high levels of readiness and maturity. At the same time, the barriers to entry for small and medium enterprises or individuals is relatively low, both in terms of technical skills and the cost of the technology, which creates significant opportunities for local communities.

The application of drone technology in capital projects is an exciting growth area. As drones become more available, regulators are gradually allowing their use at scale; and with software solutions now able to exploit the data effectively, the technology is beginning to pervade the entire lifecycle of capital projects and has filtered down to even the smallest of infrastructure projects.

The use of drones throughout a construction project provides an unparalleled record of all activities, reduces planning and survey costs, increases productivity, improves the accuracy of volumetric measurements, and mitigates or eliminates disputes over the status of a project at any given point in time. In the future, drone data will be used to automatically track construction progress and adherence to design, based on its integration with CAD and BIM models, as well as artificial intelligence (AI).

Although the construction industry has been slow in embracing new digital technologies when you compare it to other sectors, the leading global companies have widely adopted drones for capital project monitoring. Across Latin America the adoption of the technology is still limited; however, early adopters have validated and are using the technology.

Figure 1: High level use cases of UAS technology.

PLANNING	DESIGN	CONSTRUCTION	HAND-OVER	LITIGATION
Identification of terrain conditions and risks associated with the project.	High-quality 2D and 3D photogrammetry products with the most recent terrain information.	Up-to-date cyclical drone inspections with overlaid 3D as-build projects.	Data analytics to detect potential defects before the construction is handed over to an investor.	Full photorealistic documentation from each step of the construction process.
• Pre-verification of the site conditions. • Precise data for location and variants verification. • Social and environmental impact assessments.	• Precise earthwork volume calculations. • Identifying real estates to be demolished. • Connections with current infrastructure. • Right-of-way analysis.	• Construction site planning. • Cyclical reports regarding adherence to design and work schedule. • Construction safety control.	• Report with identified anomalies, and potential non-compliance with the project specifications. • Reporting safety and operational issues identified.	• 2D and 3D technical products allow the review and analysis of situations that were not documented by other means.

Source: PwC Analysis

2.

How are drones disrupting construction supervision?

2.1

Overview of the core technologies

Drone technology has been in use on construction sites (globally and in Latin America) for several years now. Currently, there are dozens of companies operating in the market which deploy and develop unmanned flying platforms, sensors, and related software solutions, with some of them focused primarily on the construction sector. Drone technology is mature enough to provide significant value to the sector.

Figure 2: Global players in the drone ecosystem.

2.

How are drones disrupting construction supervision?

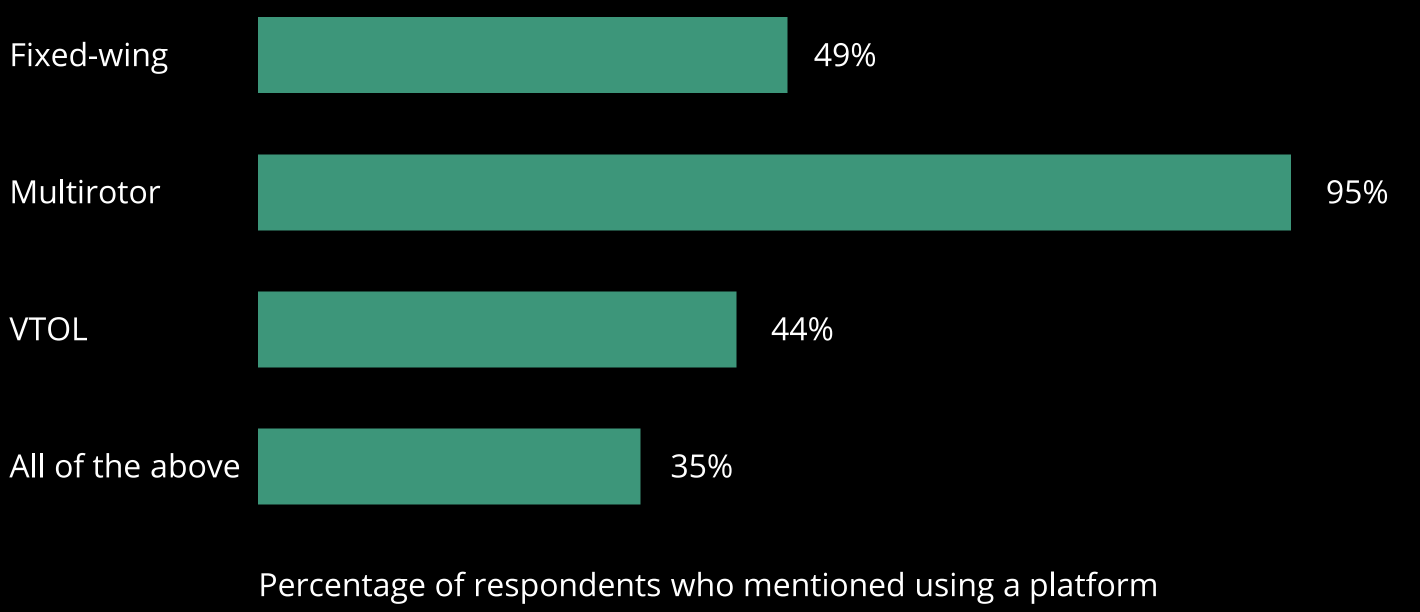
Types of drone platforms used in the construction sector

The large variety of drone platforms available on the market allows for a wide range of opportunities to match the technology to specific requirements.

Currently, there are three main types of UAV platforms. Multirotors are equipped with multiple propellers providing stable flight position and safety related to motor redundancy. Fixed-wing drones are, in structural and aerodynamic terms, largely based on manned aircraft. The newest type of drone platform on the market – and one which is rapidly gaining popularity – uses units that combine aspects of both the aforementioned constructions, often called VTOL or Hybrid drones.

Because of the great diversity of projects carried out by the construction sector, all types of UAVs are applicable and currently used in the industry. The exact types of equipment and sensors are usually individually selected in relation to the characteristics of the task and the available budget. The main elements that determine the choice of equipment for a specific task are the expected accuracy and the type of output required by the customer. Other key factors in the selection of the platform are safety requirements and compliance with local regulations which may involve restrictions on the weight of the drone, certain required safety systems, or the fulfillment of additional conditions indicated by the Civil Aviation Authority.

Figure 3: Type of UAS platform used by drone companies in LATAM



Question: What hardware do you apply for your services?

Source: PwC survey

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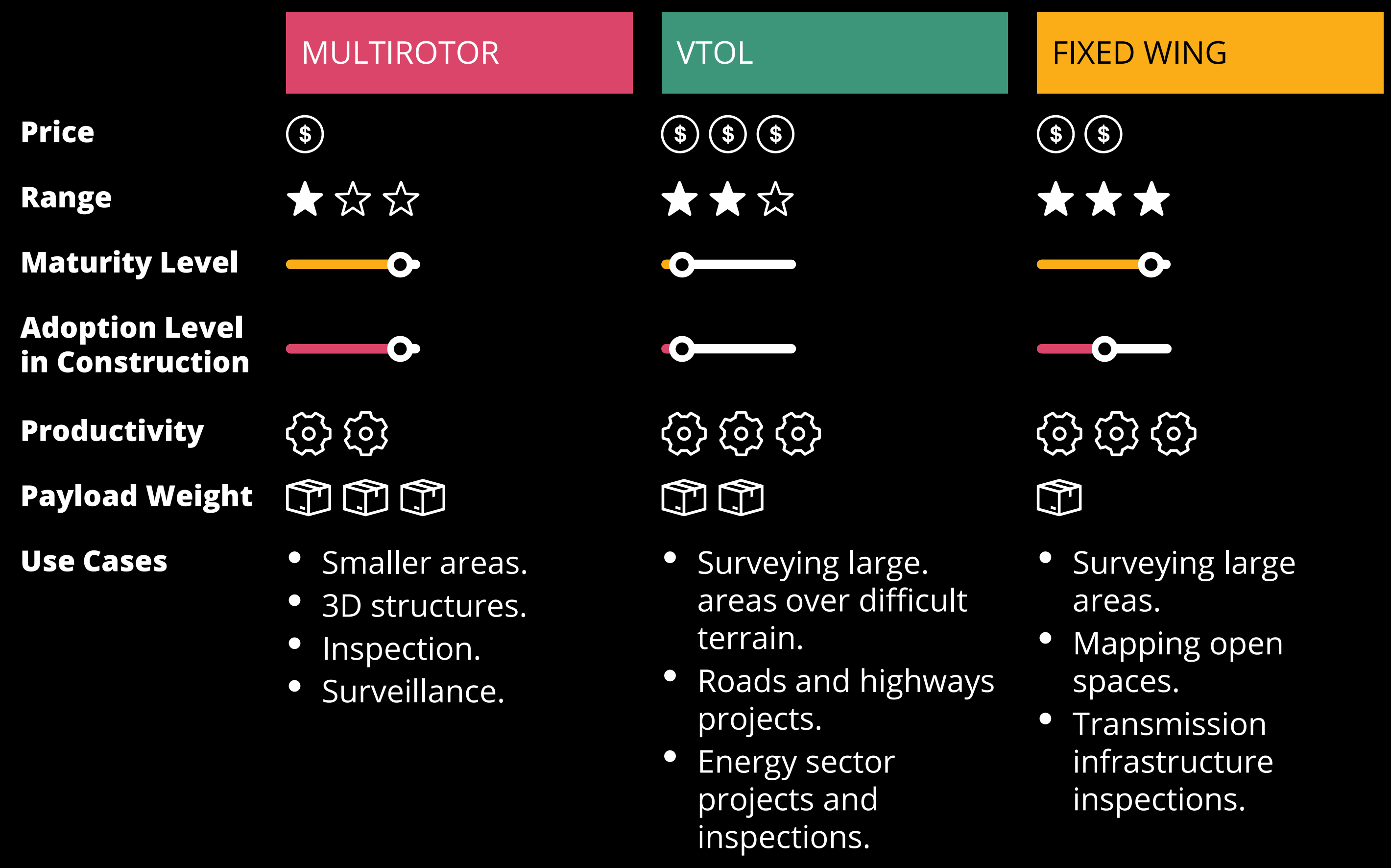
How are drones disrupting construction supervision?

Multirotor drones are the dominant type of drone platform used in the construction industry, as in many other sectors. Their popularity is primarily due to their relatively easy operation and their affordability. Brief training is enough to learn the basic maneuvers. With the ability to hover in the air, multirotors have a reduced risk of collisions and other incidents. These designs are especially useful for operating at low altitudes where there are dense buildings or other structures, and for performing site inspections where a stable craft position is required to capture a high level of detail. In addition to inspection applications, they are often used for mapping smaller areas (up to 50 ha), as well as monitoring construction sites or volumetric objects. The high popularity of these units in commercial applications is also related to their cost: the basic units of well-known brands start at $1,500, making the barrier to entry relatively low.

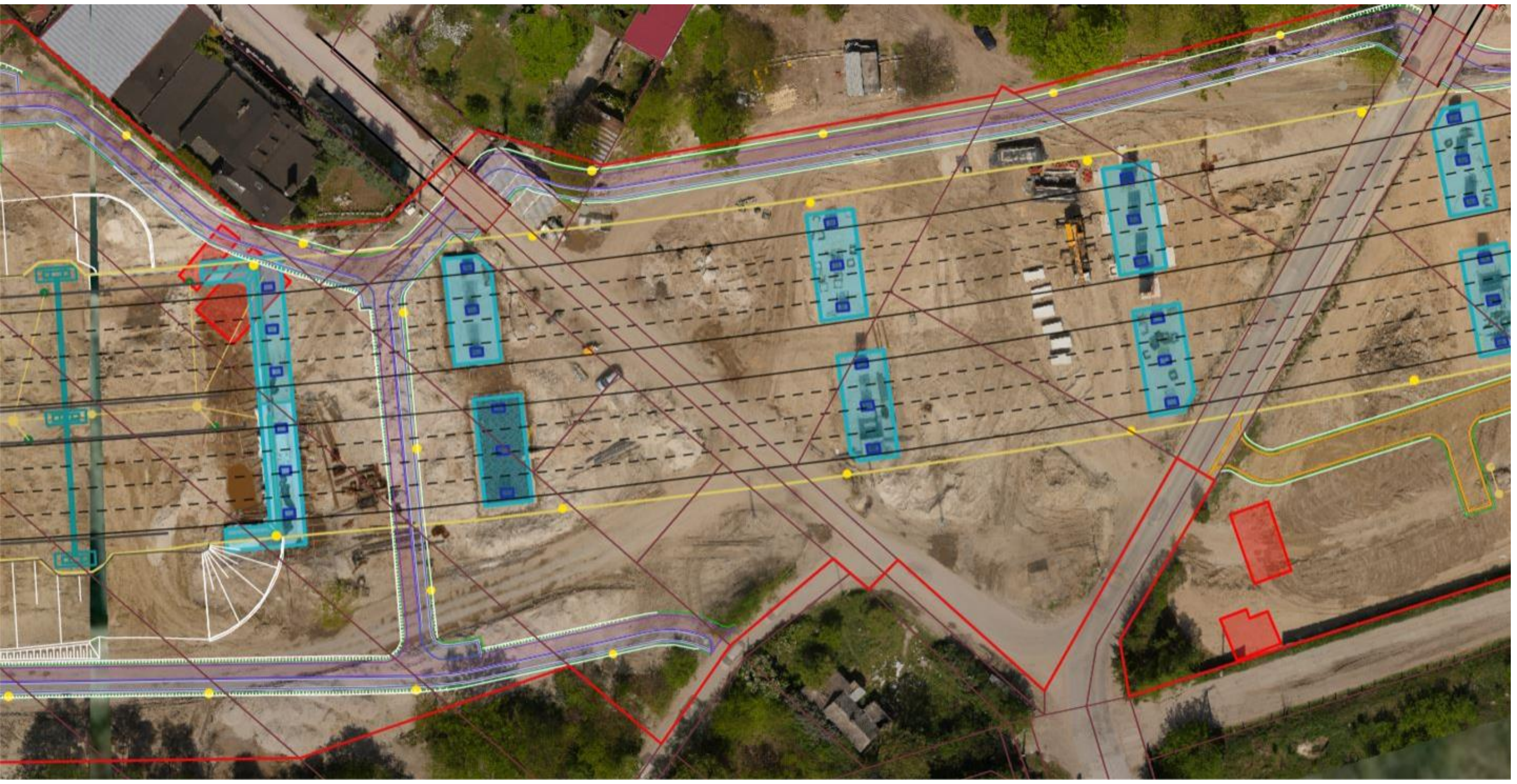
For larger areas, the use of multirotor drones becomes inefficient because of limited flight time endurance (typically up to 30 minutes of actual usable flight time). In such cases, fixed-wing platforms are used. Thanks to better aerodynamics, these units require much less energy to stay in the air, which facilitates an increased flight time averaging 1–2 hours. This translates directly into a larger operational range. Coverage of an increased area without the need for landing to replace or recharge the battery, coupled with higher flight speeds, allows fixed-wing drones to cover large areas much more quickly than multirotor drones. Controlling these units is much more complex and requires proper training. Unlike multirotor drones, such drone platforms are not able to hover in the air, so the level of risk associated with collision in the air is much higher, and therefore operations should be performed in an open space or at an appropriate altitude where there are no objects with which the drone could collide. Prices of such units are significantly higher with the most popular units starting from about $20,000–30,000.

In recent years, Vertical Take-Off and Landing (VTOL) drones are being used increasingly frequently over construction sites. These combine the cruising flight efficiency of fixed-wing aircraft with the convenient vertical landing of multirotor drones. Such platforms require a smaller area for landing – which on a construction site can be an important consideration. Due to the high starting price (from around $30,000) for the platform, they are mostly used for mapping, inspections, or monitoring the progress of the construction process for larger projects; or where the risk of collision could have serious consequences, as in the case of infrastructure of a strategic nature.

Figure 4: Comparison of the main construction types of UAV platforms



Source: PwC Analysis



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How are drones disrupting construction supervision?

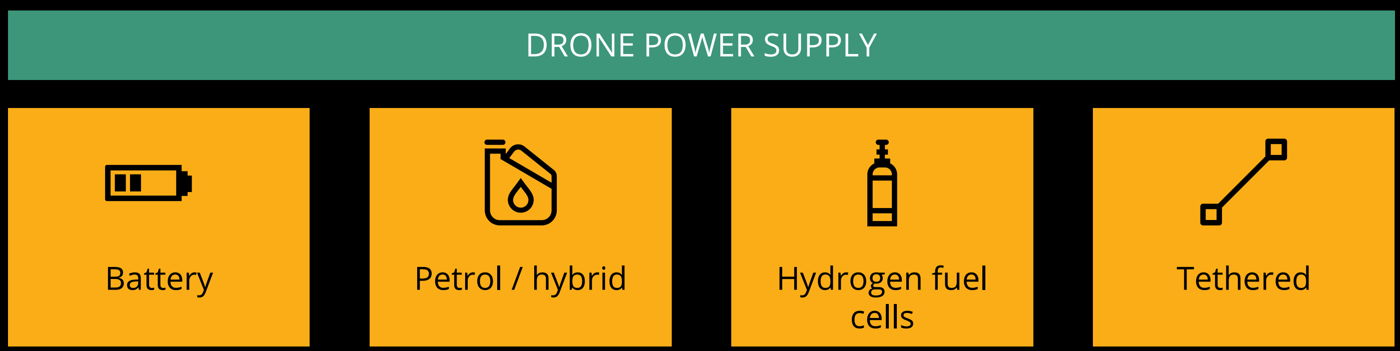
Power supply is still the main engineering challenge

Although there have been significant advancements in the development of drone technology, energy supply remains as one of the biggest bottlenecks. Most commercial UAVs are powered by electric motors and batteries. Overall flight endurance is gradually improving as manufacturers are using batteries of higher energy density and more effective engines, but the overall usable flight time of popular multirotor drones is still below 30 minutes. It is even shorter when using a heavier payload such as a DSLR camera or LiDAR.

When capturing data over a larger area, the requirement to change batteries causes inefficiency in the process. Additionally, longer flight time on a single battery also means fewer takeoffs and landings, which should translate into increased safety since these are the parts of the flight where collisions or malfunctions are most common. Moreover, some drone use cases (such as monitoring the construction of large-scale linear objects, or surveillance) are addressed most effectively through BVLOS flights with high flight endurance. Although typical fixed-wing and VTOL platforms allow operation for 1–2 hours, they are not suited to every environment and terrain, and as such, are not suitable for every use case.

Some manufacturers are working on alternative power sources. One of the solutions is hydrogen cell technology which allows a significant increase in flight time – up to 2 hours in the case of a multicopter. Another solution is to power drones in a hybrid fashion where the motors are electric, powered by a built-in battery, and a small combustion generator is mounted onboard, producing electricity by burning gasoline. Another concept worth mentioning is tethered drones, which effectively move the power source from the flying platform to the ground. In this instance, a station with energy storage is located on the ground, and energy is transferred through a thin, highly durable power wire. The biggest advantage of this solution is almost unlimited flight duration. Such drones are typically used for stationary surveillance applications.

Figure 5: Main power sources for unmanned systems



More than 95% of drones are powered by batteries (Droneii). However due to energy density limitations of current battery technology, new solutions are being developed to cope with more advanced and demanding longer flight time tasks

2.

How are drones disrupting construction supervision?

Drone payload

While flying platforms have an impact on data acquisition performance and in-flight safety, they are merely the conduit for the most important element – which is the sensor that captures the data. Initially, handheld DSLR cameras were mounted to drones, along with the hardware to trigger the shutter at the right moments. Today, manufacturers design specific cameras designed to work with drones. Their small size and low weight mean that the entire platform can stay in the air longer, and specially-designed control systems reduce the possibility of errors in data acquisition, improving overall data accuracy.

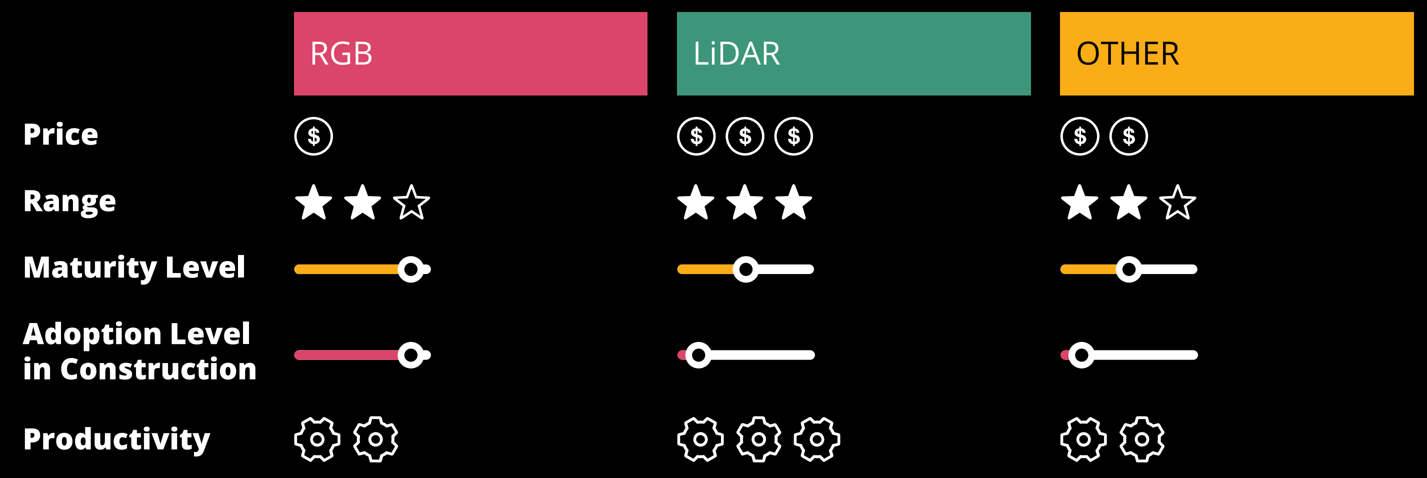
The most commonly used sensor is the RGB camera. With this tool, the best results are provided by devices equipped with high-resolution, full-frame sensors, because the larger size of the matrix allows more detail to be captured which translates into improved accuracy and greater productivity by reducing the number of images needed to cover the same area. Some of the first users of drones with RGB cameras were surveying teams, due to their knowledge of the principles of traditional photogrammetry and their awareness of drones' potential. Therefore, drones began to be used to create high-resolution maps, in the form of orthomosaics or Digital Surface Models, to meet the needs of the construction industry.

The second most frequently used type of sensor for measurement tasks is LiDAR. During a flight, the device uses a laser beam with a high density and frequency to reflect light off the objects located on the path between the drone and the ground surface, the result of which is a very dense cloud of points. The main advantage of LiDAR technology over RGB sensors is shown in areas covered with vegetation, where the laser beam is able to penetrate the vegetation and map the ground beneath it. The suitability of this technology is particularly noticeable in the creation of highly accurate terrain models (DTMs). These are used for design purposes, especially for road, rail, or transmission infrastructure. In these situations, survey work is often carried out in unfavorable terrains, reducing the accuracy of results and it can be significantly more time-consuming compared to surveys performed by drones.

LiDAR is less widely used than RGB cameras due to a much higher price point (with popular solutions starting at $30,000).

A whole range of other sensors can be mounted to the drones, one of which is an infrared or thermal camera. The data collected from such a device can be used to verify the integrity of transmission systems, detect thermal layers that have been placed incorrectly, or inspect photovoltaic panels. It can also be used to monitor a construction site for unauthorised access, especially at night, where the heat signature of a person can be seen from a distance. Other sensors gaining popularity when used with drones are gas and dust concentration detectors which can be applied to detect dangerous gas leaks, to assess whether a construction site is maintaining appropriate working conditions, or to evaluate whether workers should be equipped with additional protective equipment.

Figure 6: Most prevalent sensors used with UAS for industrial application



Source: PwC Analysis

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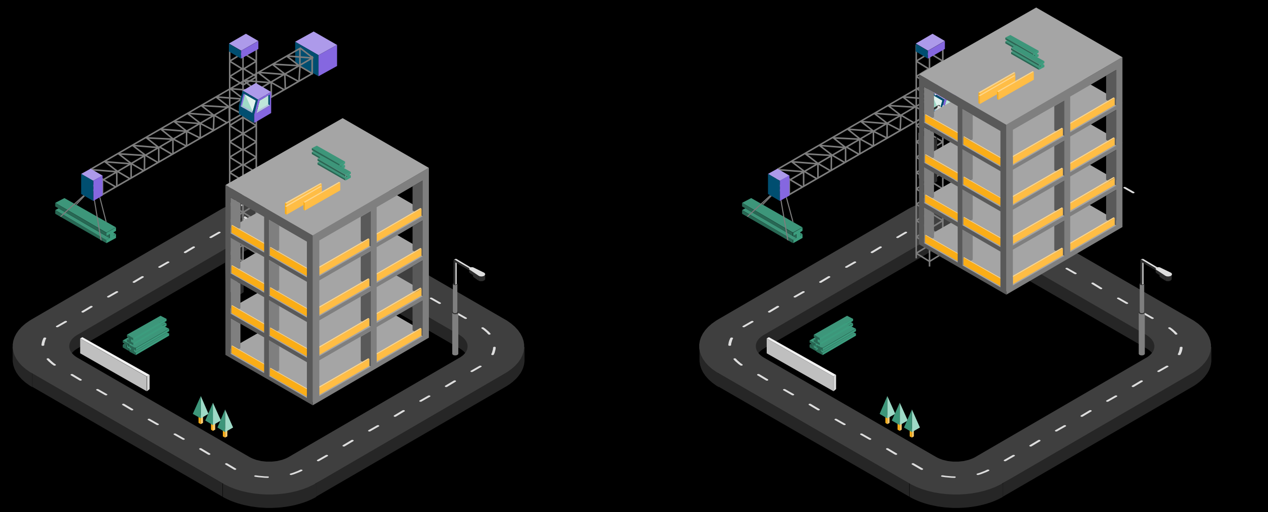
How are drones disrupting construction supervision?

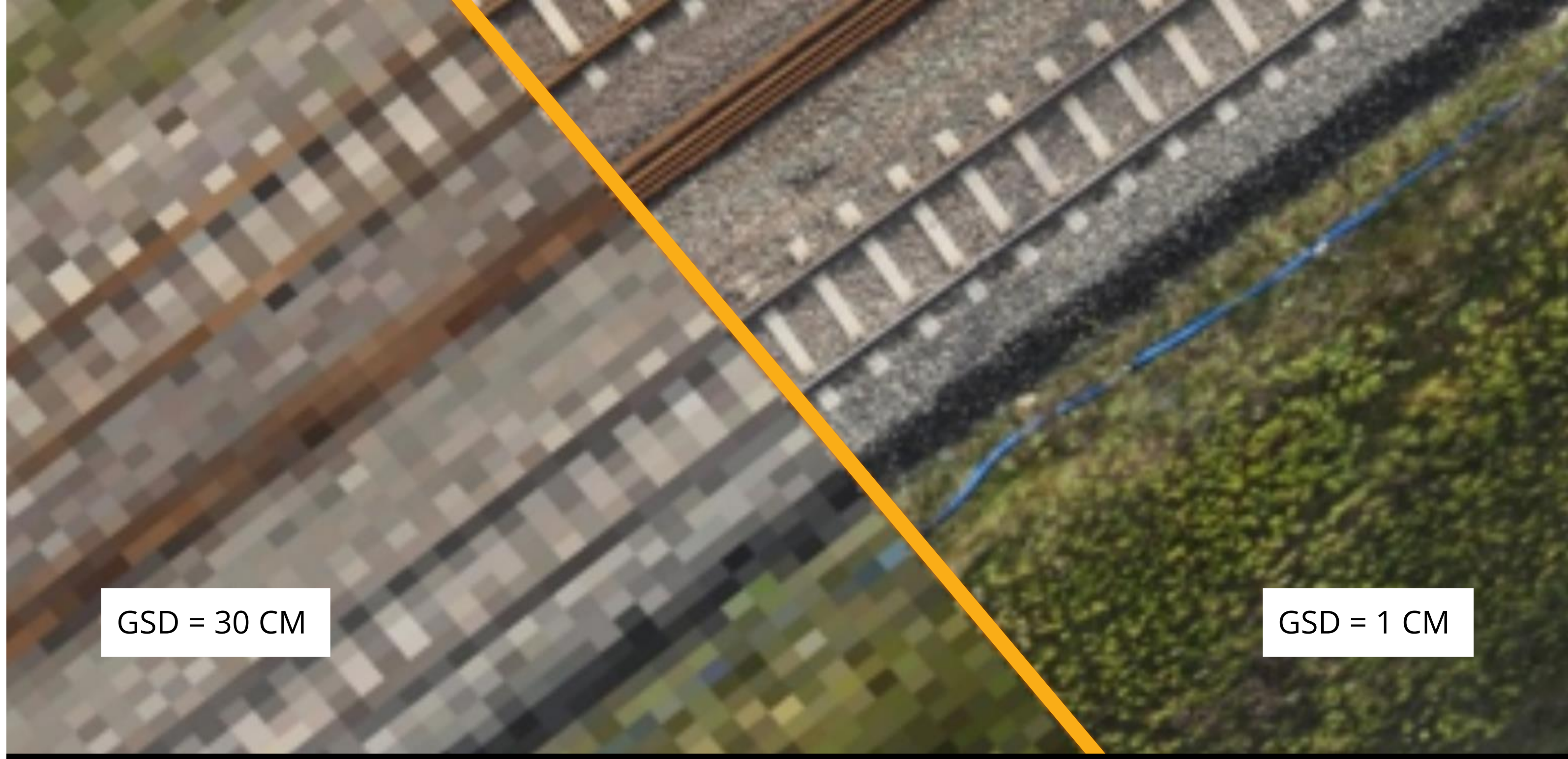
Why is it so important to record a drone's position accurately?

The overall quality of the drone data used in construction supervision – such as orthomosaics, digital surface models and 3D point clouds – is only as good as the raw data captured by various drone sensors. These output data built out of hundreds or thousands of separate images which are processed together using a dedicated photogrammetry software solution. The quality and accuracy of the final product depends on several technical, environmental, and geometrical factors, but one of the most critical elements is the location accuracy of where each separate image was captured.

The typical positioning accuracy of Global Navigation Satellite System modules (such as GPS and Galileo) installed on popular drone models is at a level of several meters.

Figure 7: Illustration of accuracy aspects in photogrammetry products





Information Box

HOW ACCURATE IS THE DRONE DATA?

Ground Sample Distance (GSD) is a parameter describing the spatial resolution of drone data, or what dimension of terrain is represented by 1 pixel on an image. The lower the drone flies, or the higher the resolution of the camera it uses, the smaller the GSD.

For a resolution of 1 cm GSD, the maximum accuracy of the data is 1–3 cm. With a better sensor, conducive conditions for GNSS signal and sufficiently varied terrain of operations, it is possible to obtain results in the lower range of accuracy. In a typical scenario in the construction sector the resolution used is at the level of 2–4 cm, depending on the use case, making drones a very suitable working tool that meets stringent industry requirements.

With such accuracy, photogrammetry software is capable of creating an accurate 3D representation of the construction site (high relative accuracy), but it is not able to place it in the exact correct location of the geodetic coordinate system (low absolute accuracy). Such positioning accuracy is good enough for use cases such as volumetric measurements, asset inspections, or safety management and surveillance.

The more advanced construction use cases such as progress monitoring or adherence to design, require drone data to be overlaid on top of CAD/BIM models, and the comparison of drone inspections from various dates. For the data to match up, high absolute positioning accuracy (down to several centimeters) is required. It can be achieved using more so-called 'Ground Control Points', and/or RTK (Real-Time Kinematic) /PPK (Post-Processing Kinematic) positioning technology.

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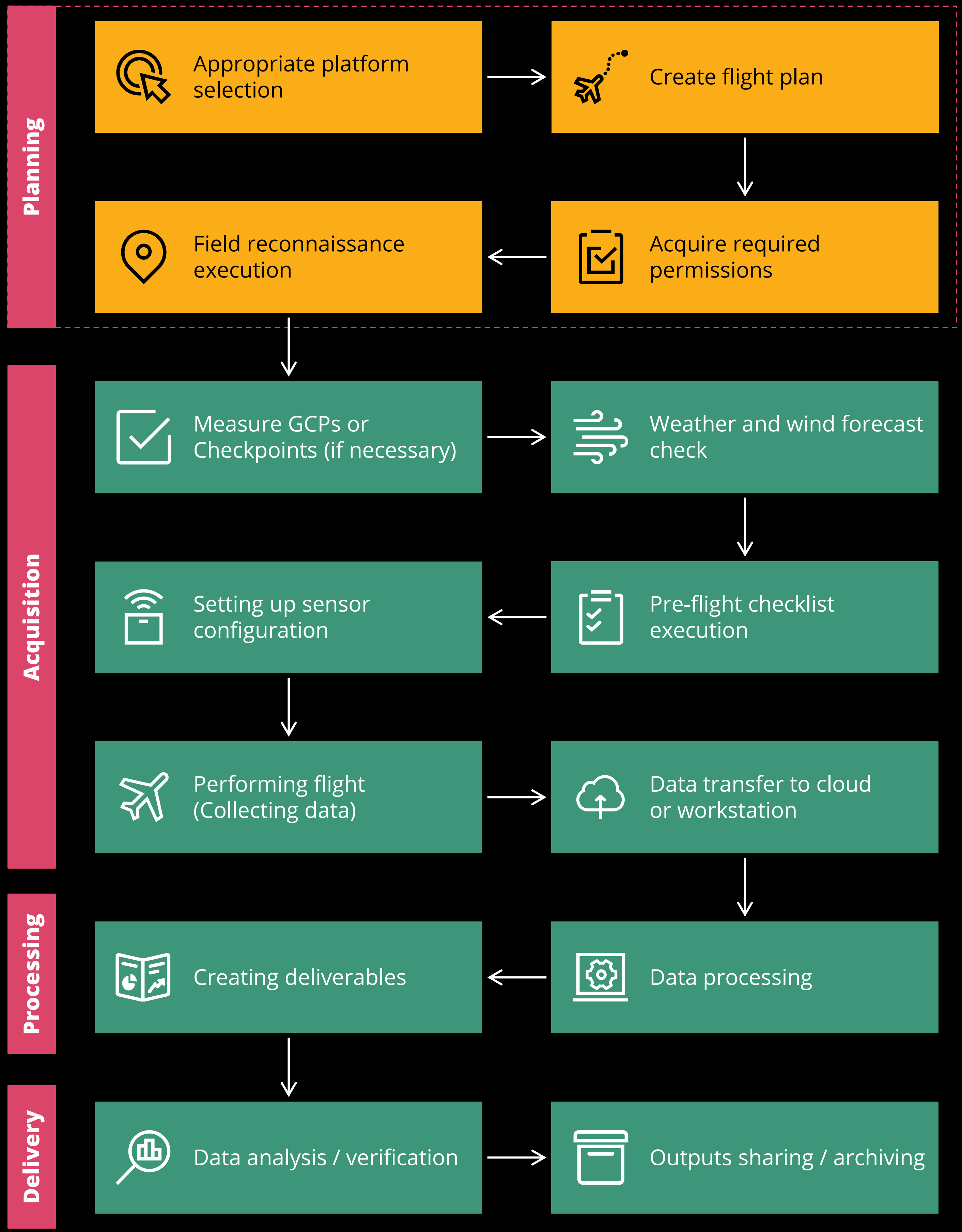
How are drones disrupting construction supervision?

To reduce the number of GCPs needed, the construction sector is increasingly using drones equipped with so-called Real-Time Kinematic (RTK) or Post-Processing Kinematic (PPK) technology to improve the positioning accuracy of the raw images captured. It can improve the accuracy from several meters to several centimeters. RTK works by connecting a drone to a network of reference base stations installed around countries (CORS) via a radio or cellular network to improve the accuracy of the satellite positioning. In the region, the base station network is developed and maintained by the SIRGAS organisation. Whenever the availability of real-time data is not available (e.g., in less densely populated areas) the industry uses PPK technology – which requires the data to be processed in the back office, rather than receiving instant GNSS corrections.

Figure 8: What does the end-to-end process look like for drone use in construction?



Source: PwC Analysis

2.
How are drones disrupting construction supervision?

Software

In a typical scenario involving an aerial drone survey or inspection with an RGB camera, multiple geotagged images of the construction area are captured from different angles. Data captured in the field is saved on a physical memory card and then transferred to a computer. In some cases, the data can be used in its raw format for manual analysis, as is often done in difficult-to-reach places. In a more advanced scenario, the data is processed into a more technical product using photogrammetry software. The system combines separate raw images into 2D maps or orthomosaics, elevation models, and 3D point clouds. Such data can then be used to extract and measure information such as distances, area measurements, or volumes.

The processing can be performed in a desktop application where the user has full control over the data processing, or through one of the available cloud-based platforms. The choice depends primarily on the sophistication of the use cases, budget, and practical considerations such as the availability of a fast Internet connection. Cloud-based applications offer other functionalities besides data processing related to data storage, management, visualisation, and analysis. Cloud-based online portals for interacting with the data are critical because the drone data might be multiple gigabytes in size and therefore too large to use for browsing or analytics in an offline desktop environment. Additional consideration should be given to processing time. In a typical scenario, depending on the size of the construction surveyed, the data can be available between several hours up to 24 hours after the drone has landed.

The full value of drone data can be unlocked when used together with CAD/BIM environments. Popular software companies like Autodesk and Bentley Systems can read popular drone file formats; however, they are not yet ready for full integration that would enable advanced analytics and AI solutions on a large scale.

Figure 9: Future technology trends shaping the use of drones in construction

TECHNOLOGY	DESCRIPTION
AI	Automated tools for detection of issues with adherence to design or work schedule, based on drone data.
EDGE computing	Processing and analyzing drone data in real-time from a drone or in the field.
5G	Sending drone data for processing or analysis in real-time.
UTM	Air traffic management system to integrate drones safely within the airspace, enabling large-scale deployment of drones.
Docking Station	Docking box for drone deployment, charging, and data transfer without human intervention in the field.

Source: PwC Analysis

2.

How are drones disrupting construction supervision?

2.2

The challenges for the construction sector in Latin America and Globally

The deterioration of the infrastructure in several Latin American countries, coupled with the explosion in demand for urban housing and better public services, have been some of the main construction drivers in the region. To take full advantage of the opportunities these trends are generating, the construction sector will need to find new ways to address some of the key challenges and barriers to growth and profitability.

The following table summarizes some of these challenges which are particularly important in the Latin American context (such as cost overruns or delays, litigation, among others) and how drones can help. Further analysis on these key issues is included in the next section.

Figure 10: How drones can address challenges in the construction industry

AREA	PRIMARY ISSUE	DRONE SOLUTION	DRONE TECHNOLOGY READINESS	POTENTIAL IMPACT
Project delays and cost overruns	Caused mainly by unclear governance and procedures, as well as inefficient communication between multiple project actors. Adequate measures should be taken to clarify and streamline end-to-end processes. Low productivity translates into project delays and cost overruns.	Digital solutions should include the implementation of drones to acquire detailed data for purposes such as precise daily reports which enable more efficient management of the construction process.	★★☆	
Limited digitalisation and technology adoption	This causes low productivity and inefficient communication between multiple project actors. Adequate measures should be taken to clarify and streamline end-to-end processes.	Drone technology enables the creation of a digital twin of the construction site on a cyclical basis and overlays it with project data for construction intelligence.	★★☆	
Personnel shortages	Capital projects require large amounts of manpower. However, the cyclical and seasonal nature of the work leads skilled personnel to seek more stable employment.	High efficiency of UAS data acquisition allows for a reduction in staff required for surveying and supervision tasks, or for a redirection of capacity to other tasks.	★☆☆	
Safety	Construction has one of the highest accident and fatality rates of any industry. In addition to the severe human consequences, this negatively impacts project costs and schedules.	Drone technology eliminates the risks associated with inspections at height, while high-resolution products facilitate the detection of hazardous areas.	★★★	
Material wastage	High levels of waste through poorly optimised asset management processes and current needs, resulting in higher project costs and lower profits.	Accurate monitoring of material status and demands during the construction process allows for more precise order quantities.	★★☆	
Sustainability	Data acquisition in the planning and construction process is time-consuming and often produces insufficient levels of detail. Revisiting sites, as well as clearing vegetation for surveying, can result in negative environmental consequences.	The use of drones reduces interference with the environment, reduces the level of pollution emitted, and can also help in excluding sites that may be important for the protection of natural biodiversity.	★★★	
Litigation	Delays in the project, added to the lack of objectivity, can lead to lawsuits and lengthy litigation.	Drone images offer truthful, exact, and near real-time information. In many countries, drone documentation is accepted in court.	★★☆	

Source: PwC Analysis

2.

How are drones disrupting construction supervision?

Project delays and cost overruns

In the construction industry, projects – especially complex ones – are rarely completed within the originally agreed time and budget. Also, trends show that while cost overruns have been decreasing in Asia and Europe over recent years, there has been an upward drift in LATAM (Flyvbjerg and Sunstein, 2016).

Globally, most infrastructure projects take at least 10–30% longer to complete than originally planned, and the cost associated with these delays is on average 20–30% of the budget. In LATAM, 75% of infrastructure projects suffer from cost overruns (with an additional cost ranging from 36% to 103% depending on the type of infrastructure – see table below) and 65% of the projects have delays of between 6 and 18 months (IDB, 2016).

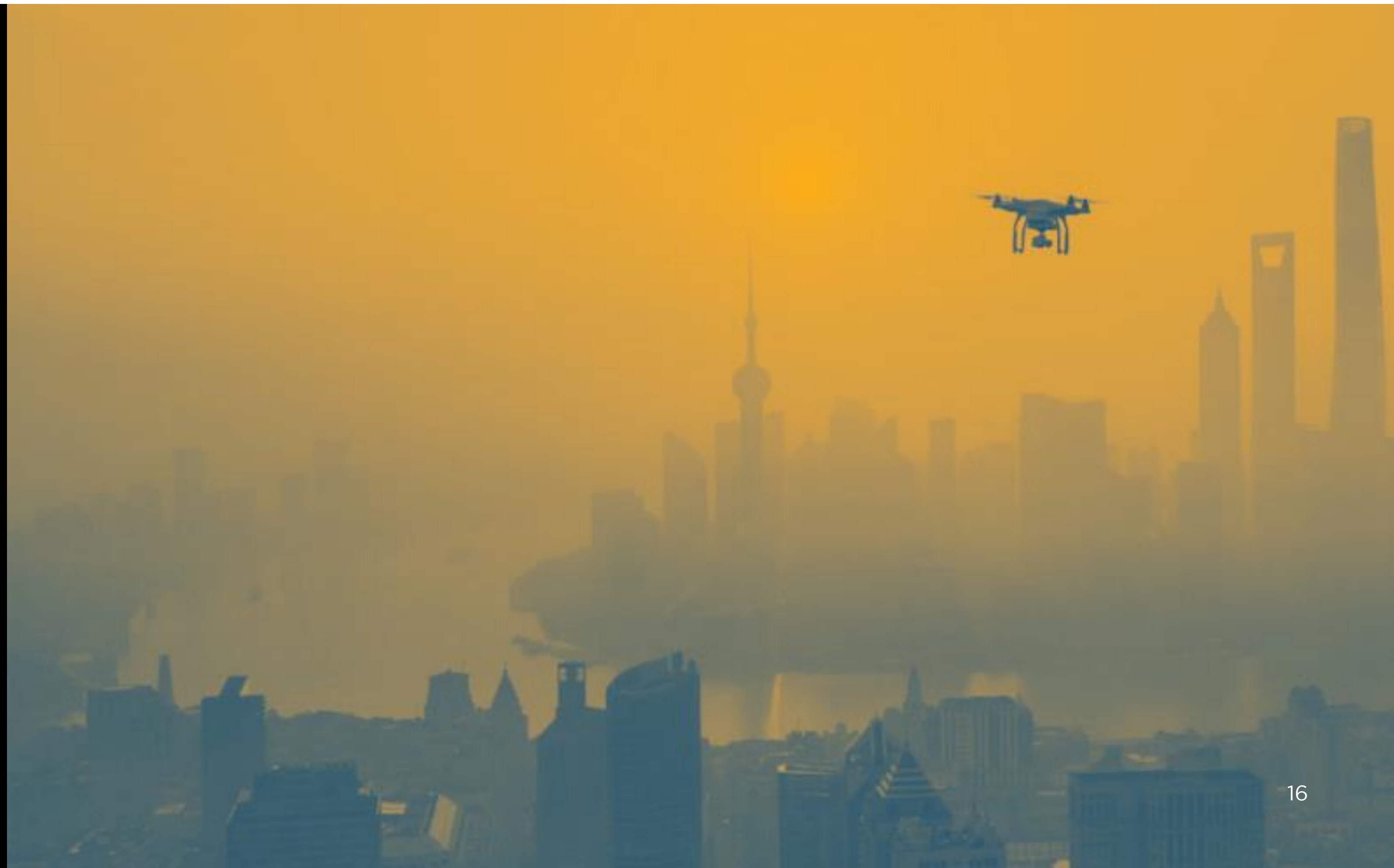
Many factors contribute to delays and cost overruns, such as changes made during construction, inefficiency in management and execution, lack of complete information, and errors in initial cost estimations, among others. In addition, the COVID-19 pandemic has had a major impact on construction, limiting the availability of workers and materials.

It's worth mentioning that in infrastructure projects financed by multilateral development banks (which contribute between 10-12% of total infrastructure investments in the region, or 20% in smaller economies), cost overruns are lower. This is mainly due to the fact that these projects are usually prepared, implemented, and supervised subject to higher standards than those of country-funded projects (Serebrisky et al. 2019)

Figure 11: Average cost overruns (% over budget) for infrastructure projects in Latin America and the Caribbean and globally, by type of project

	LATAM & CARIBBEAN	WORLD
Dams	103%	95%
Railways	59%	40%
Power plants	36%	36%
Roads	53%	23%
Average	48%	28%

Source: Flyvbjerg (2016). Note: sample of 806 projects around the world



2.

How are drones disrupting construction supervision?

Figure 12: Key challenges that are causing delays and cost overruns in LATAM

Question: Key challenges that are causing delays and cost overruns (execution-related challenges in order of relevance). The percentage is calculated considering the number that each of the challenges is mentioned out of the total number of entities that responded

Source: PwC survey

UAS technology can be one element used to mitigate delays and additional costs by improving the level of communication and providing a transparent view and actionable insights about the construction site. This translates to important actions, such as improved safety and efficiency – e.g., through better planning, identifying conflicts and dependencies, minimising work overlap, or enabling just-in-time material delivery, and more. These can all lead to higher productivity, compensating for delays associated with other independent factors.

Limited digitalisation and technology adoption

One of the main problems in the construction industry when compared to other sectors is low labor productivity, which increased at an average rate of 1% per annum over the last two decades compared to an average global economic growth of 3,1% (OECD data, World Bank data). Multiple causes explain this disparate evolution, and slow technology adoption stands out among them.

Drone technology can contribute to improving the overall situation by digitalising the data captured through the construction lifecycle. Currently, the verification of supervision and control of construction is still predominantly a manual process, where a team of engineers inspect the construction site, taking photographic data, descriptive documentation, and geodetic measurements. Such a process is time-consuming, and in complex projects there is a high risk that errors will not be identified or properly assessed.

Data from the industry shows that the implementation of advanced digital solutions is not, by itself, enough to replace experienced employees because, especially during the early stages of drone implementation, staff are needed to monitor and ensure the correctness of new systems – such as predictive analytics technology, for example (PwC US, Oxford Economics, 2020). Stakeholders in the construction sector are therefore looking to catch up by investing in technology and hiring professionals with digital skills to help move the construction industry forward into 'Industry 4.0'.

According to research conducted by PwC, job openings requiring digital skills in the global engineering and construction sector almost doubled between 2016 and 2018, driven by the need to implement digital solutions faster and due to a growing shortage of experienced staff. As a result, some companies have had to hire retired professionals and 75% of CEOs in the engineering and construction sector are concerned about there being insufficient numbers of experienced employees to carry out projects as planned.

2.
How are drones disrupting construction supervision?

Personnel shortages

The construction labor market is characterized by a certain seasonality and cyclicality due to weather conditions, economic cycles, availability of funds and finance (public or private), etc. Skilled human resources are required (especially in large projects, where more expertise is often needed) and construction companies normally hire part of the personnel only for the duration of each project. Often the local markets, even when supplemented with workers from abroad, are unable to meet the demand.

In this context, the utilisation of drone technology can maximise the efficiency of the staff, reducing accidents, lowering costs, and speeding up the progress of the work. The use of drones on construction sites for surveying and surveillance purposes allows a team of several people to be replaced by a drone and operator duo, and the same tasks can be completed in a much shorter time.

Safety

Worldwide, at least 108,000 workers die in the workplace each year. Data from various industrialised countries shows that construction workers are 3 to 4 times more likely to die from on-the-job accidents than other workers.
In the developing world, the risks associated with construction work can be 3 to 6 times higher (ILO, 2015).

Moreover, the construction sector is facing the highest rate of fatal injuries of any industry. In the US, around 20% of fatal injuries at work are in the construction industry, although workers in the sector account for less than 5% of the total US labor force (US Bureau of Labor Statistics).

In LATAM, the incidence rate of occupational accidents (probability of suffering an accident based on the total number of workers in the sector) is especially noteworthy in construction, with fatal injuries particularly worrying.
In Argentina, for instance, there were 22,500 incidents reported in construction in 2020 (9% of all work-related accidents nationwide) and 41 deaths; with an incidence rate of 61.5 per 1,000 workers (Ministry of Labor, Employment and Social Security). In Mexico, the Mexican Institute of Social Security registered 33,000 accidents in the building construction and civil engineering works industry in 2019 (8% of the total), and among them, 159 fatalities.
In Uruguay, the information on work accidents for all sectors in the 2014–2017 period shows an annual average of 35,000 claims, 12% of which were in construction, with an incidence rate in construction of 4.9 accidents per 1,000 workers in 2017 (BPS). Examples from other countries in the region show similar trends.

Drones would not solve the problem entirely; however, the use of this technology can help to mitigate the risk of workers' injuries. UAVs can access dangerous, hard-to-reach locations on construction sites and capture necessary data faster and with a better view. Significantly, this reduces the risk of falling, which accounts for 1/3 of all construction deaths and is the leading cause of fatal injuries in the sector (OSHA, 2022). In addition, construction supervision by drone enables deployment on an ongoing basis, to collect information which might not otherwise be gathered or overseen, from insufficiently marked or secured places. Drones can monitor concentrations of dangerous gases and dust, which can inform supervisors as to whether the environment is safe to work in or if personnel will need to be equipped with additional safety measures.

2.

How are drones disrupting construction supervision?

Wastage and sustainability

Material prices are currently very unstable as a result of the disruption of supply chains caused by the COVID-19 crisis, coupled with high demand due to a large number of projects started both before and during the pandemic. This has significantly affected the cost of materials used by the construction industry. A wide range of materials are used on construction sites and the average cost of these materials year-over-year (2021–2022) has increased by approximately 21% in the US market. (Construction Outlook, JLL, 2022)

Minimising waste is a very important element, both for the contractor – to improve project profit – and for the environment, to reduce pollution and emissions. The construction industry has contributed significantly to filling landfills with debris. In some countries, the share of construction waste can account for 50% or even more of all urban solid waste. Moreover, about 30% of all construction materials delivered to a building site end up as waste (Chakkrit Luangcharoenrat et al, 2019)

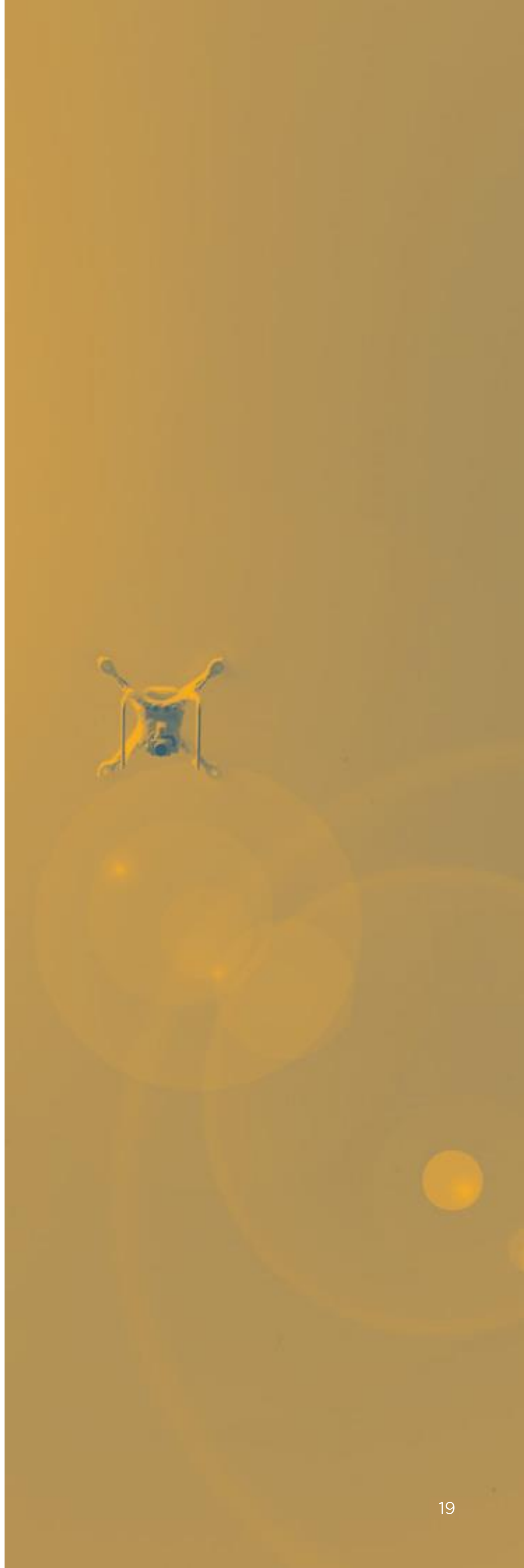
Project monitoring and supervision augmented with UAS allows for more accurate management of the materials accumulated on-site, reducing the amount of buffer needed to complete tasks without downtime. In addition, most construction projects involve a lot of earthmoving, resulting in heavy machinery and frequent travel by survey crews, making cuttings or clear-cuts in order to carry out surveying measurements. The use of drones mitigates interference with the environment and limits emissions into the air by reducing the amount of fuel burnt.

Litigation

In recent decades, many infrastructure projects in Latin America have been affected by serious conflicts. Of 200 projects analysed by the IDB in the region, 36 were canceled due to conflicts, while the Environmental Justice Atlas shows 423 cases of environmental and social conflict currently in progress in the region (IDB, 2017).

Errors and omissions that occur on the construction site as a result of human error and through incomplete or faulty technical and contractual documentation are one of the major factors of disputes in construction projects. Regarding the NBS (National Building Specification) and their construction industry surveys, one-third of respondents were involved in a dispute during the one-year period. There are many reasons for this with the major ones being errors and omissions in the field and documentation which are related to poor project control, inadequate communications, and slow decision-making. In 2021 average dispute values reached $52,6 million and the average dispute lasted around 15 months. (Global Construction Disputes Report, Arcadis, 2022; NBS, 2018).

Data obtained by drones during progress monitoring can be valuable evidence and provides additional security in the case of any possible claims. Among the wide range of available drone outputs is data on vegetation damage or soil contamination by hazardous chemicals stored on building sites which can be particularly useful in litigation matters involving environmental violations. Penalties imposed by government bodies on investors or contractors can be very severe, not only from a financial perspective but also from a legal perspective, resulting in withholding construction permits or even facing criminal charges. Material registered by drones offers supervision companies the opportunity to minimise the risk of environmental devastation by detecting issues at an early stage or providing evidence of which entity is the culprit so that they can be held accountable for repairing the damage.



2.
How are drones disrupting construction supervision?

2.3

Applications of drones in the construction sector

Drone technology can have a significant impact on the construction industry by improving the supervision process, reducing risk, and improving the overall efficiency of work on the construction site. Drones can be of special value when it comes to surveying and monitoring large-scale capital projects. They can also be very useful for efficient construction management of sizable areas and vast-scale linear infrastructure objects – such as roads, railroads, or pipelines.

In addition, in the case of multistory buildings, or highly complex infrastructure projects, each stage of the construction process takes longer and carries greater risks (compared to residential or standard-size architecture projects), which in turn can be very costly in terms of subsequent repairs or penalties associated with delays. Large international construction companies like Skanska, Strabag, and Vinci have been using drones for several years for surveying tasks and monitoring construction sites. Most of them have their own engineering units equipped with drones, and the data is processed internally, in accordance with a developed methodology. Smaller companies, where the level of digitalisation and adoption of new technologies is lower, rely more often on full or partial outsourcing in the form of aerial surveys performed by their own staff, and data being sent for further analysis to companies specializing in processing photogrammetry and data from UAVs.

Drones are used at many stages of construction projects and are not limited to surveying and supervision activities. In the pre-construction phase, they can be deployed to obtain geospatial data to create mapping documentation and to match project details to existing conditions. In the execution phase, they can complete various tasks which fall within the broad sphere of 'construction supervision', to verify if work is progressing according to project plans, declared schedules, legislation, standards, safety regulations, and contract conditions. The use of drones does not end with the completion of construction; on the contrary, they can be invaluable for technical inspections before handover and to carry out necessary maintenance subsequently.

2.

How are drones disrupting construction supervision?

Figure 13: The most important stages in the construction process and how drones can assist (1/3)

PHASE	ACTIONS	DRONE INVOLVEMENT	DRONE PRODUCTS	APPLICABILITY OF UAS TECHNOLOGY	POTENTIAL IMPACT ON PROCESS EFFICIENCY
PRE-CONSTRUCTION					
PLANNING AND DESIGN	**Project concept**	-	X	X	X
	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**	-	X	X	X
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.	X		

2.

How are drones disrupting construction supervision?

Figure 13: The most important stages in the construction process and how drones can assist (2/3)

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		

2.
How are drones disrupting construction supervision?

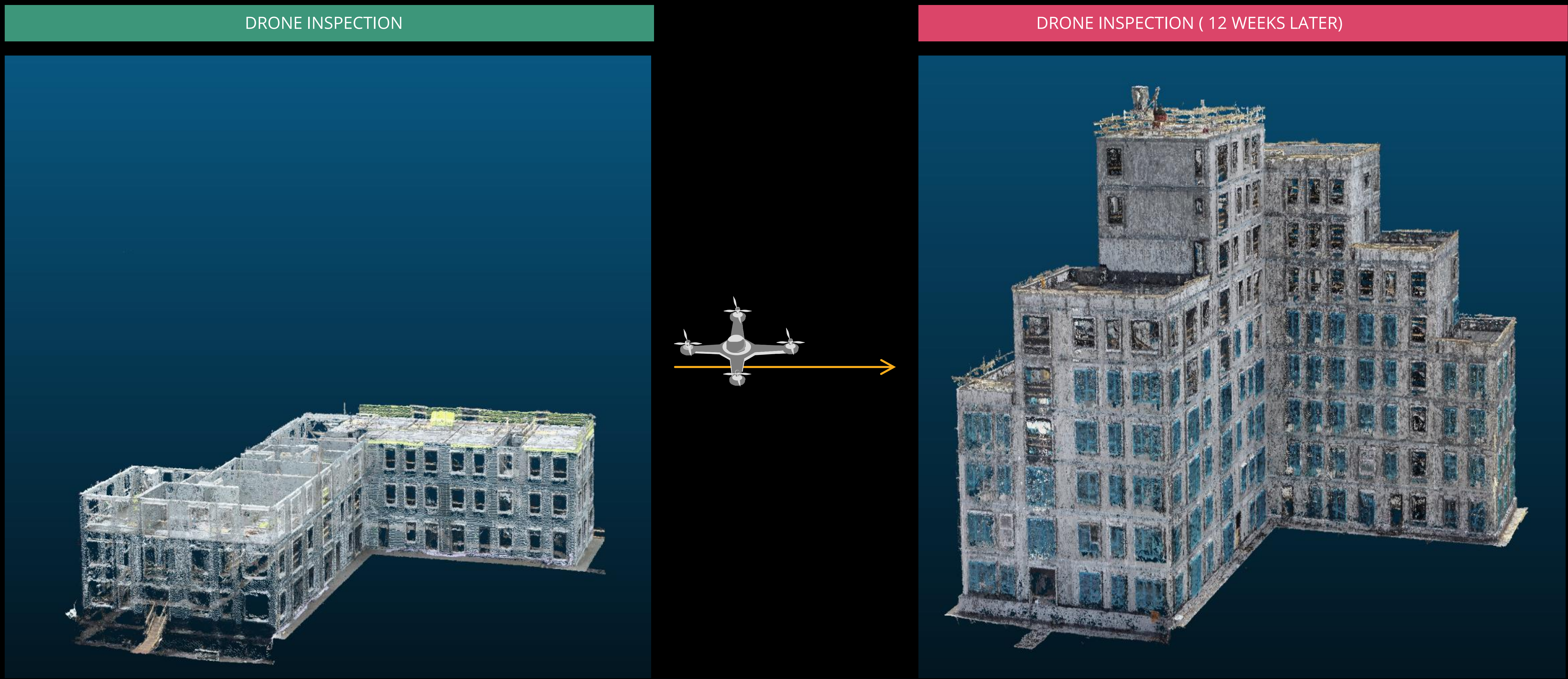
Figure 13: The most important stages in the construction process and how drones can assist (3/3)

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**	-	×	×	×

Source: PwC Analysis

2.
How are drones disrupting construction supervision?

Figure 14: Progress monitoring based on 3D point cloud generated based on drone flights



2.
How are drones disrupting construction supervision?

As indicated before, the construction industry is seeing high interest in drone technology and larger companies have made UAVs a permanent part of their inventory. Drone technology helps to support decision-making processes before the first shovel breaks ground and can contribute to noticeable savings throughout the construction process. While automated flying systems, cameras, and other sensors are at a high level of development, allowing for high-quality and accurate data, there is often a lack of knowledge on how to use this technology effectively. This is especially relevant in the construction industry, which for years has had one of the lowest levels of digitalisation of any industry.

The integration of drone data with systems used on construction sites to monitor progress, make orders, or prioritise tasks is another way in which drones add value for construction supervision and management tasks. Standardization of the format and scope of data provided by different entities in the construction process – by introducing Building Information Modeling (BIM) methodology on a wider scale – will streamline work and eliminate many task conflicts that can occur on a construction site due to imperfect project management.

From a technological point of view, drone hardware seems ready for broader utilisation in many applications; however, some obstacles remain unsolved. One is legislation, which in many countries is still at an early stage of development and does not allow beyond-visual-line-of-sight (BVLOS) operations. It is often difficult to obtain the necessary permissions and sometimes relevant procedures are lacking. Another barrier is insufficient data-analysis software, meaning the majority of the work must be performed manually. Working on high-resolution, resource-intensive data is cumbersome and inefficient.

On the other hand, the difficulty in calculating the financial benefits of using drones in construction projects and the reluctance to implement digital project management solutions are additional factors that slow down the adoption of drone technology among stakeholders in the industry.
For example, most companies that have used this technology were not able to quantify certain benefits such as the reduction in time, necessary personnel, or even other more qualitative aspects (such as improvements in efficiency and early detection of errors). Until broader steps are taken in all these areas, the full potential of the technology will not be unleashed.

3.

What is the level of adoption of drones in infrastructure and construction supervision in Latin America?

3.1

Overview of the drone sector in Latin America

The LATAM region has been fast to adopt drone technology for specific use cases. The first civilian UAS manufacturers in the area started to develop their devices in the early 2000s and most players joined between 2010-2020. In 2021, there were at least 36 active drone hardware manufacturers and integrators in the region, with 20 in Brazil alone, typically offering UAS platforms focused on addressing specific market niches such as agriculture or mining. The hardware and software from international technology companies is also widely available.

The leading use cases in the region are related to agriculture, where the adoption of UAS and digital technologies is above the global average even compared to developed countries, with Brazil and Argentina presenting the most advanced applications. In Chile, nearly every major mining company uses drones for surveying, which brings significant benefits over conventional measurement methods. However, the adoption of the UAS across capital projects is still in the initial phase of development.

3.

What is the level of adoption of drones in infrastructure and construction supervision in Latin America?

Figure 15: UAS Market Value and Growth by Country

Country	Forecasted market value in 2021, [USD Mn]	Forecasted market value in 2026, [USD Mn]	CAGR '21-'26
Brazil	67.0	321.6	37%
Mexico	19.1	100.2	39%
Argentina	18.8	94.7	38%
Colombia	11.9	67.8	42%
Peru	11.7	64.3	41%
Bolivia	7.6	39.3	39%
Venezuela	7.3	36.4	38%
Chile	6.3	30.9	39%
Paraguay	3.4	15.9	36%
Ecuador	2.4	11.9	38%
Caribbean	2.3	11.6	39%
Suriname	2.2	10.7	37%
Uruguay	1.6	7.8	37%
Nicaragua	1.3	6.4	37%
Guyana	1.1	5.9	39%
Guatemala	1.0	5.3	39%
Honduras	0.9	5.1	43%
Dominican Rp.	0.8	4.5	41%
Panama	0.8	4.2	39%
Costa Rica	0.6	2.6	40%
El Salvador	0.4	2.0	38%
Belize	0.2	1.1	39%
Total	**168.6**	**849.4**	**38%**

Source: PwC analysis, World Bank

The value of the drone services market in Latin America was estimated at USD168m in 2021 (See Figure 15). The region offers a wealth of opportunities for the commercial drone industry, with a predicted compound annual growth rate (CAGR) of 38% over the next 5 years.

Currently, the biggest market for drone services in Latin America is agriculture. The construction industry is also a significant market for drone applications, primarily because Latin American countries require significant investment in their transportation and utilities infrastructure. Another factor is sustainable development; specifically, the transition to clean energy from renewable sources. These types of capital projects are strategically important for countries across the region and are also suitable environments for drones due to their higher complexity.

3.

What is the level of adoption of drones in infrastructure and construction supervision in Latin America?

Regulatory overview across the region

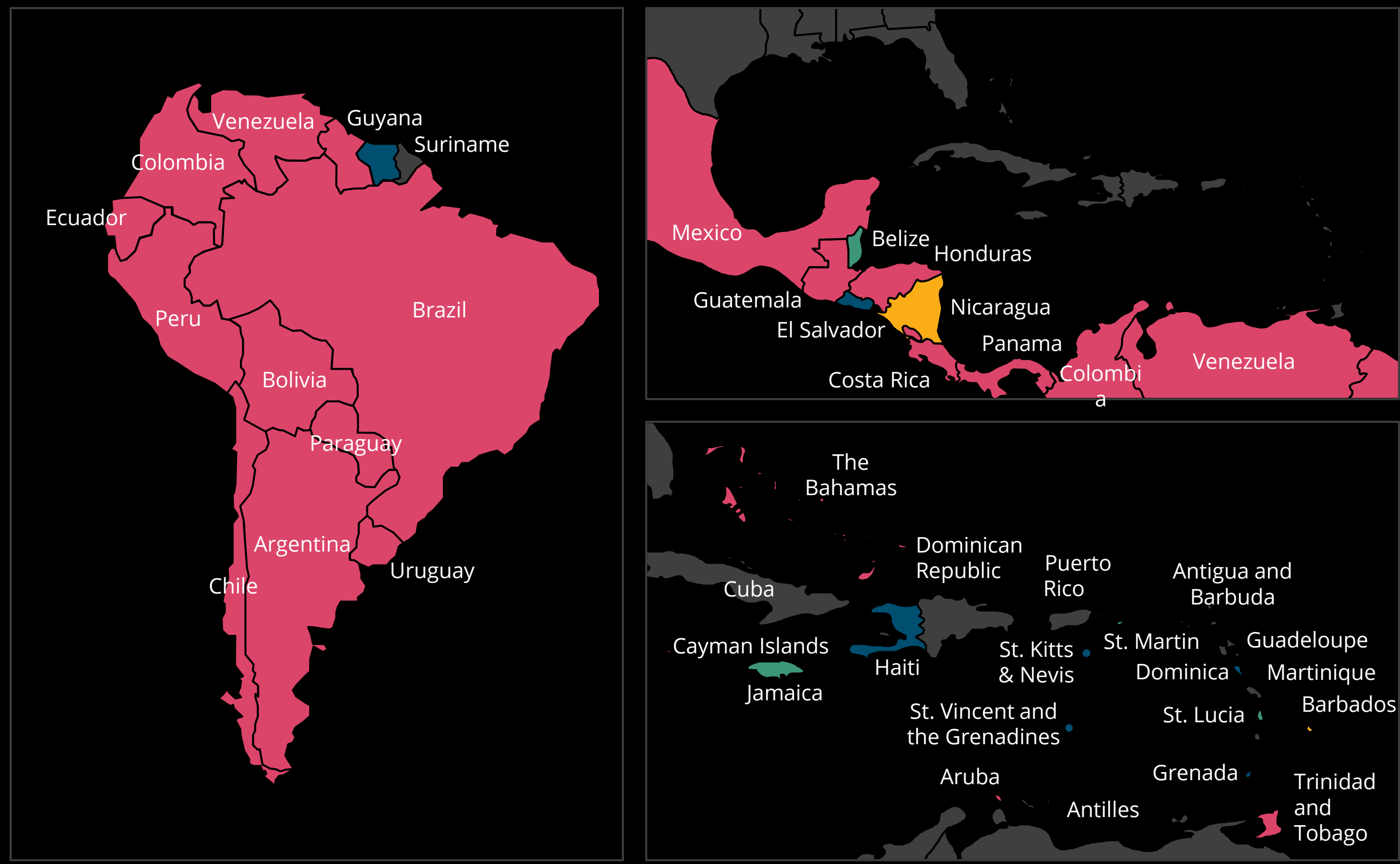
The first regulations for drone operations in the region were established in Guatemala in 2013 as the aviation community in the country started to actively use drones for crop spraying. Other countries followed and today the only places where the use of drones is still prohibited are Nicaragua and, partially, Barbados.

Countries across Latin America have developed drone regulations under their own national Civil Aviation Authorities (CAA) – bodies responsible for local airspace-related legislation. In some cases, they are following International Civil Aviation Organisation (ICAO) recommendations, while others are influenced by more advanced regulation from mature drone ecosystems, such as the United States or the European Union. As a region, they do not follow a unified framework at the moment (the exception being the Eastern Caribbean CAA, which has unified rules for seven islands).

Typically, regulations across Latin America follow global trends, although progressive regulations related to BVLOS, for example, are not widely available in the region.

The level of digital services offered to drone operators, such as drone registrations, flight authorisations, and digital maps of the airspace zones are also highly limited—with some notable exceptions including Brazil and Uruguay.

Figure 16: Regulatory overview across the region



- Countries that have established dedicated drone regulations
- Countries that have published regulations as part of general aeronautical law or as unofficial guidelines
- Countries that have not published any guidelines or regulations and follow universal recommendations
- Countries where drones are prohibited

* Drone regulation analysis was performed for 35 countries around Latin America. Cuba and overseas territories were excluded from the analysis.

Source: PwC analysis, World Bank

3.

What is the level of adoption of drones in infrastructure and construction supervision in Latin America?

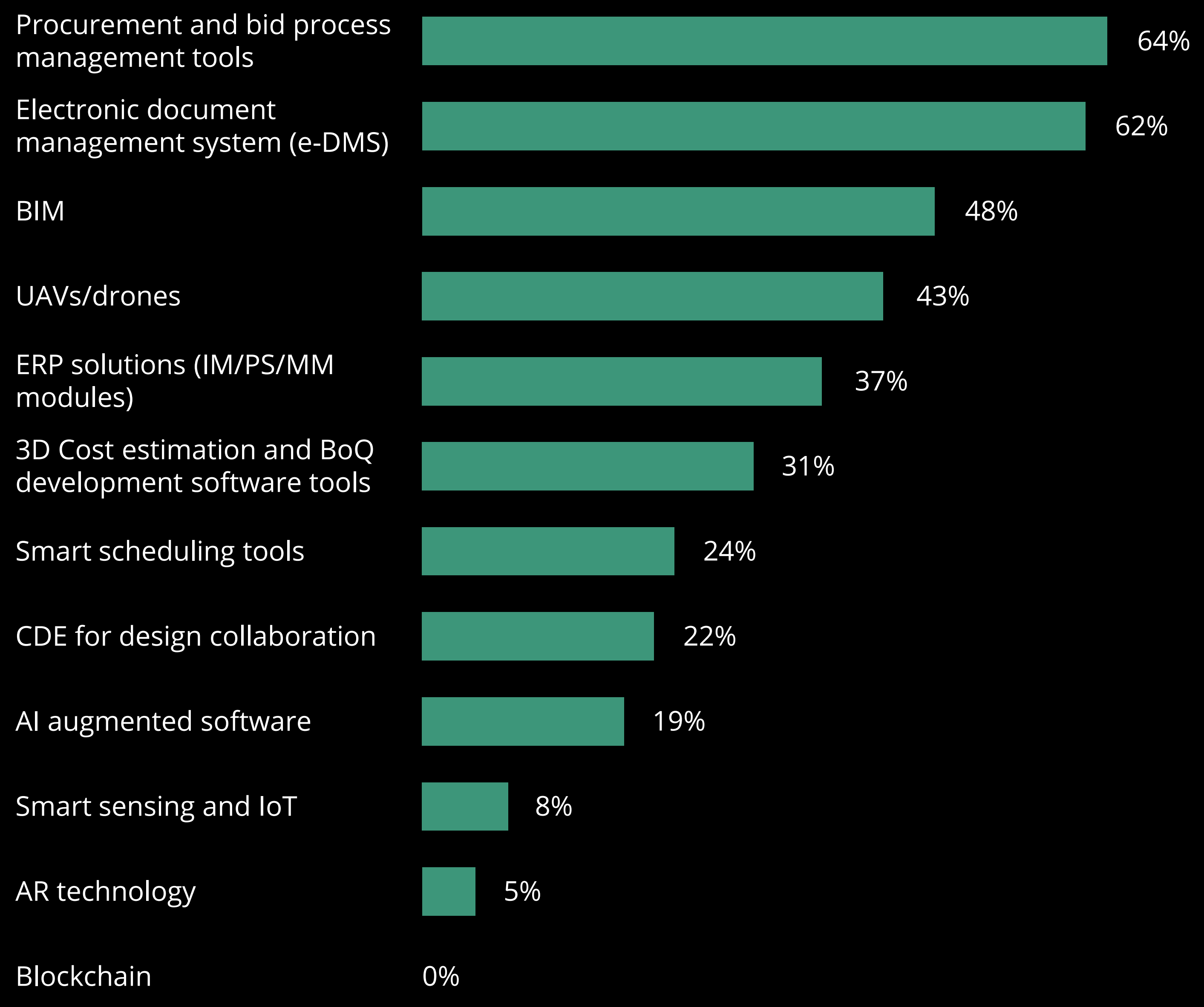
3.2

Adoption of UAS technologies among infrastructure and construction stakeholders

The construction industry has traditionally involved a large amount of manual labor and has been one of the slowest sectors in terms of its adoption of digital technology. The challenging environment of complex construction projects does not make it an easy place to test new solutions. Technologies like Augmented and Virtual Reality, Robotics, 3D printing, IoT, and Machine Learning solutions very often fail to meet the practical and challenging requirements of the construction industry, and after piloting, few are further scaled by the organisations.

Nevertheless, following international trends, the construction sector in Latin America has been slowly incorporating the use of different digital technologies to optimize processes and increase efficiencies. The responses obtained by the PwC survey for the present report conducted among different stakeholders show that digital tools for managing contracting and bidding processes, as well as the electronic document management systems (e-DMS), are the most used technologies (utilised by 6 out of 10 respondents), followed by BIM and drones (4 out of 10).

Figure 17: Technology use in infrastructure projects in LATAM



Question: Top digital solutions being implemented in your organization for purposes of construction supervision, use across multiple projects. Percentage calculated on the total number of responses received.

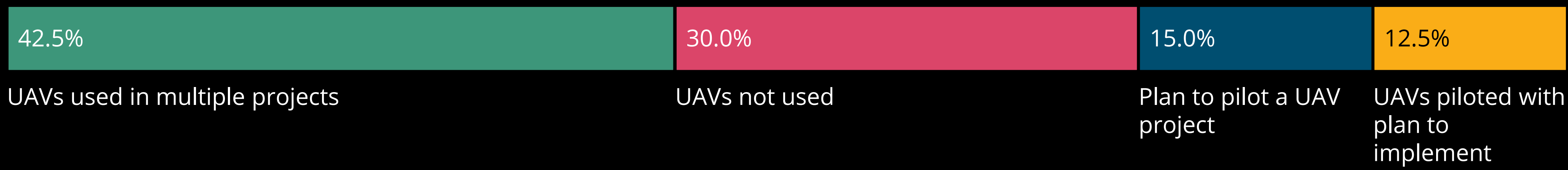
Source: PwC survey

3.

What is the level of adoption of drones in infrastructure and construction supervision in Latin America?

In addition, it is worth noting that all respondents stated that they use at least one form of new digital technology. This shows that, albeit slow to change in comparison to other sectors, technology has been incorporated into the different phases of infrastructure and construction projects. However, it should be noted that most of the responses to the survey were obtained from large construction companies with extensive experience and background. It is likely that the state of technology adoption is lower when we consider the whole construction sector including small and medium companies.

Figure 18: Maturity level in the use of drones



Question: Maturity level of drones being implemented in your organization for purposes of construction supervision. Percentage calculated on the total number of responses received.

Source: PwC survey

In addition to the almost 43% who claim to make extensive use of drone technology, a further almost 28% have piloted or plan to pilot it. Almost a third of those surveyed have not used or even piloted this technology. One explanation of this could be that the benefits of applying the technology have not been fully quantified and/or disseminated, in addition to the barriers mentioned before. What is noteworthy is the fact that there was not a single answer about canceling plans to implement the UAV solution after the pilot project. This indicates that the technology, in the testing phase, generates outcomes that are satisfactory enough to convince companies decide sooner or later to use the technology in their daily work to achieve broader profits.

3.

What is the level of adoption of drones in infrastructure and construction supervision in Latin America?

Adoption of drones among different stakeholders

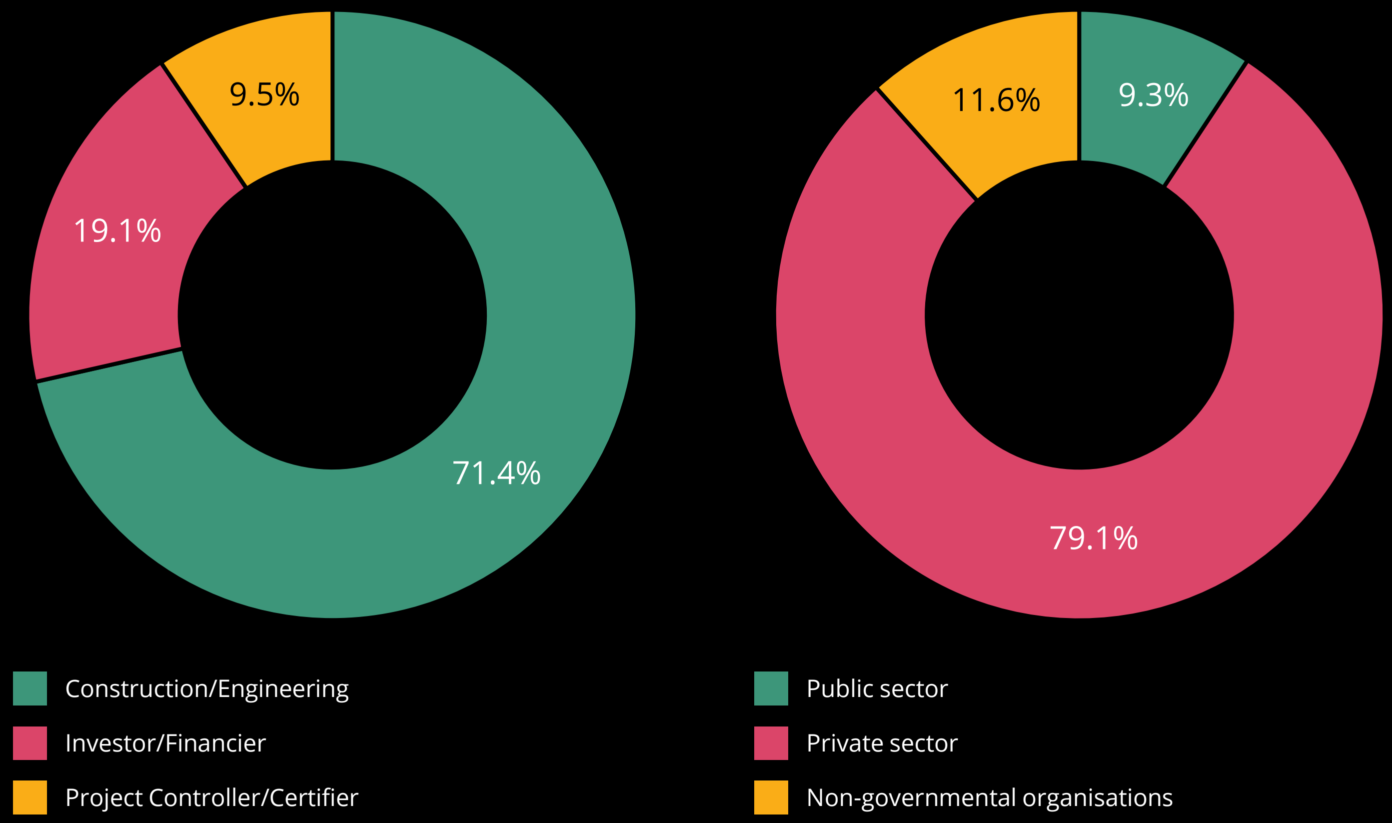
In terms of the type of organizations that implement drones in construction supervision (private, public, or non-governmental institutions), private sector actors report the highest degree of adoption with 79% of this sector using the technology according to PwC's survey results. Among non-governmental institutions, adoption was significantly lower, with only around 11% of respondents having used the technology. The results of the survey do not provide conclusive output regarding public sector agencies, but the conducted interviews suggest that in this sector the degree of adoption is still quite low (around 9%).

In regard to the principal role or business area of the stakeholders, three groups were considered: Construction/ Engineering, Investor/Financier, and Project Controller/ Certifier. Evidence from the survey shows that most Controllers/Certifiers that responded to the survey use drones in their infrastructure projects. Having objective, quality, and real-time information is one of the attributes most valued by this group.

In the case of Investors/ Financiers, the practice is slowly gaining ground (both privately and among multilateral organisations). For this group, the advantage of being able to carry out supervision remotely stands out as particularly relevant as it reduces costs and travel times in addition to providing evidence to verify compliance with the institution's policies and safeguards. Among the Construction/ Engineering companies consulted, most have used drone technology at least once, but almost 20% say they have never used drones (nor do they plan to do so in the short term) in any of their activities.

It should be noted that, in many cases, firms that carry out supervision activities in the construction sector do not use drone technology (at least not in most cases) because the other parties do not either (government, etc.). In other words, the incentives to implement this technology would be greater if all parties were at the same level of adoption.

Figure 19: Composition of the survey respondents according to group of stakeholders.



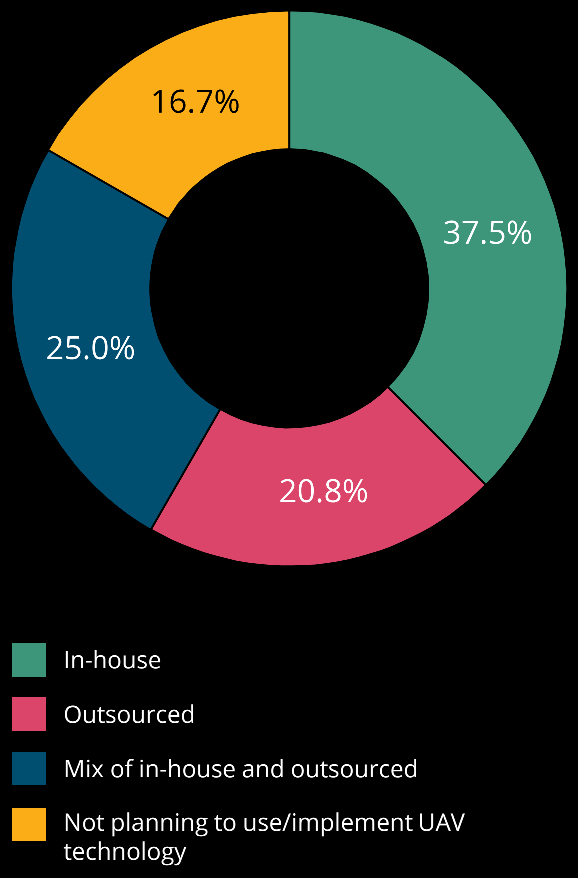
Question: Area where you conduct most of your business
Source: PwC survey

Question: Type of organization

3.

What is the level of adoption of drones in infrastructure and construction supervision in Latin America?

Figure 20: Models of UAV technology implementation



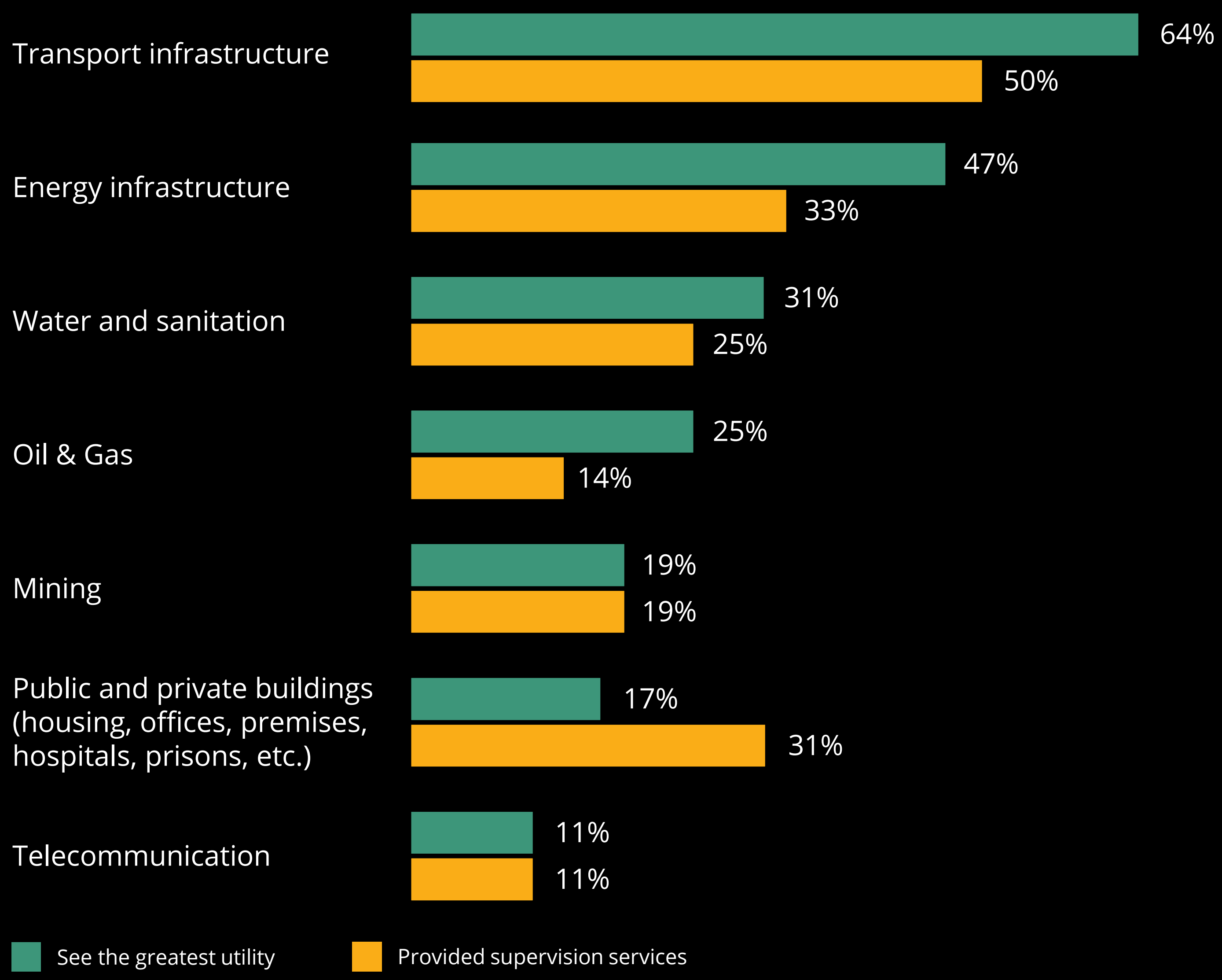
Question: How are you planning to implement UAV technology in your organization?

Source: PwC survey

Implementation of drone technology

Regarding the way that UAV technology is implemented across the organisations, almost 40% of the respondents claimed to develop the practice internally (with their own UAV hardware and trained operators), and 25% do so by combining the company's own resources with external ones. In particular, large companies that operate globally tend to have internal teams. Almost 21% of respondents outsource the service, either due to the complexity of complying with the regulations of a certain country or to give greater flexibility in the type of drone technology that is applied according to the characteristics of the project.

Figure 21: Branch of the construction where supervision services are provided, with opinion on the suitability of drones



Question: In which branch of the construction industry do you typically provide supervision services? Percentage calculated on the total number of responses received.

Source: PwC survey

Adoption of drones among the different sectors

Its use has spread throughout different areas, with notable participation in transport (especially in linear works such as railways and roads) and energy infrastructure. In this regard, according to the results of the survey carried out by PwC, among those companies that use drones, the top 3 branches that carry out construction supervision activities are the transport and energy infrastructure, and Public and private buildings.

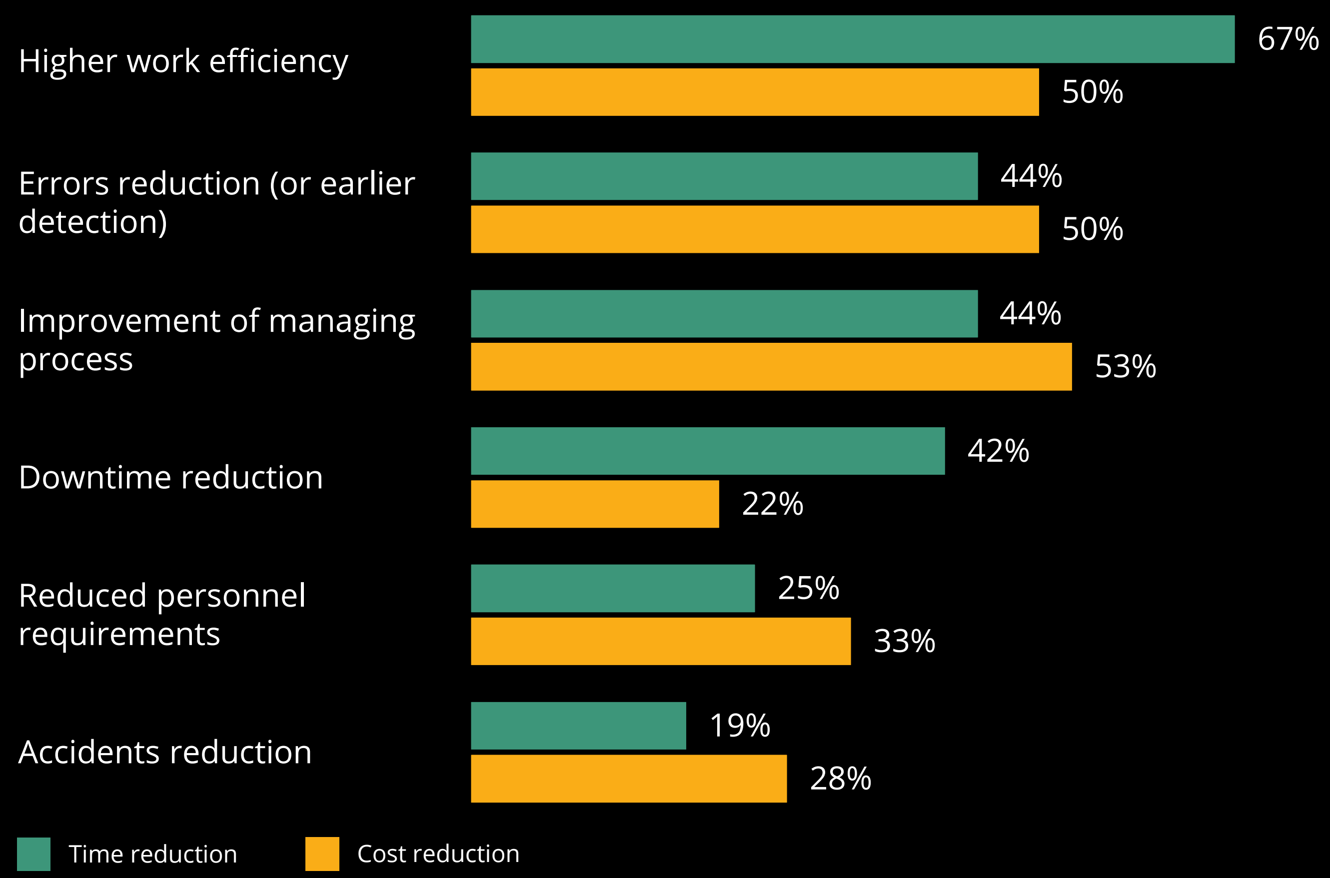
3.

What is the level of adoption of drones in infrastructure and construction supervision in Latin America?

Benefits and satisfaction

Among those respondents to the PwC survey who have used drones, 94% said they were satisfied or very satisfied. In part, this is explained by the improvements obtained in time and costs from its use: 75% of respondents reported time and cost benefits of using drones in the supervision phase, and higher benefits are noted in other stages where implementation of drone technology is less complicated (such as design). Time saving was considered one of the most important factors when choosing this technology, due to the agility and speed with which high-quality information can be obtained.

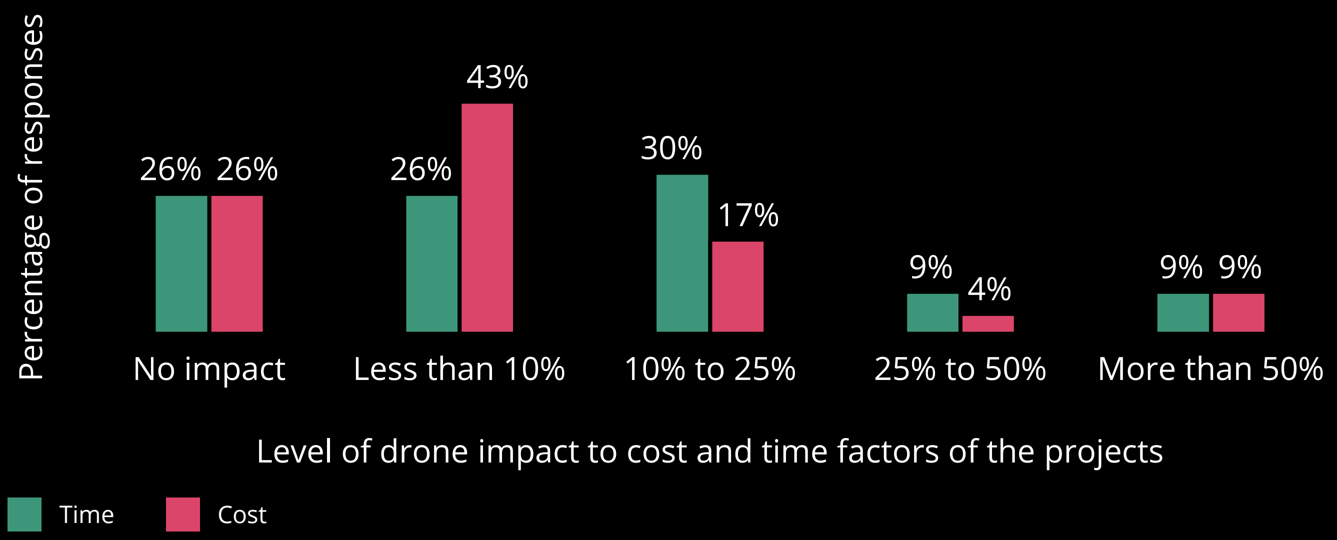
Figure 23: Fields where drones contribute to cost and time reduction in supervision



Question: In which fields drone technology contributes to cost reduction and time reduction of construction supervision? Number of responses in each case.

Source: PwC survey

Figure 22: Impact of the UAV solution implementation in the supervision



Source: PwC survey

3.

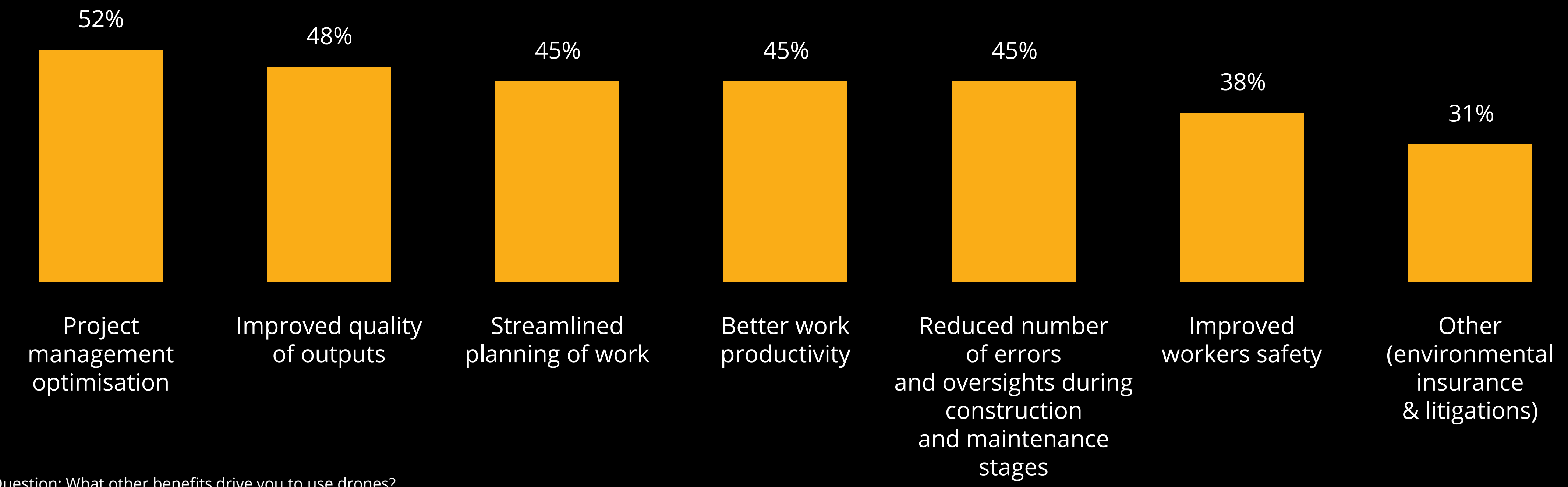
What is the level of adoption of drones in infrastructure and construction supervision in Latin America?

Even in the case of those survey respondents that do not declare a positive impact on cost or time, satisfaction is high, indicating the existence of other benefits that have not been quantified. For example, obtaining objective and truthful information, better safety conditions for workers, or improved access to remote areas. In addition, in some cases, drone technology has not been employed to improve existing practices but to carry out an activity that would otherwise be impossible, for example, to access areas that are entirely inaccessible on foot.

In brief, the survey results confirm that beyond time and cost reduction, stakeholders perceive many other benefits including the simplification of work, productivity improvements, and reduction in the number of errors.

Much depends on the characteristics of the project, for example – large space construction projects such as roads will be benefit more from better project management and and improved overview of the current status of work, while the supervision of multi-story building construction in confined urban space may benefit more from the increased safety for personnel.

Figure 24: Other benefits stimulating the use of UAS technology



Question: What other benefits drive you to use drones?

Source: PwC survey

% of the total number of those who responded mentioned this benefit

Of those who use drones, 100% also use other technology. This may indicate:

a. that drones are not the first technology that a company decides to implement and/or

b. that the capture of benefits in the use of drones grows when it is augmented with another complementary technological tool (see for instance the case of the IDB's infradigital platform discussed further in the report).

3.
What is the level of adoption of drones in infrastructure and construction supervision in Latin America?

Selected cases and experiences

The following table summarises selected experiences and infrastructure projects in which drones have been used, highlighting different benefits and relevant considerations based on interviews developed with public and private stakeholders as part of the present report.

Figure 25 (1/5) Selected cases and experiences

PROJECT	DESCRIPTION	ACTIVITIES IN WHICH DRONES WERE USED	REPORTED BENEFITS	OTHER CONSIDERATIONS
Construction of UPM 2 pulp mill Industrial megaproject Uruguay 2020-present	Construction of UPM second pulp mill in Uruguay with a capacity of 2.1 million tons annually. Estimated initial investment of USD 2,700 million, in addition to complementary investments in roads, ports, electricity grid, housing, etc.	Work progress certification (complementing the field equipment and traditional techniques). Photographic survey of the site and its surroundings and videos for use by the communications team.	Improvement in project management and decision making. Better quality of information. Much more precise information and with very frequent updates. The use of drone images is complemented by the extensive use of CCTV systems to achieve valuable records for possible uses in litigation but also in normal work coordination discussions with contractors. Safety. The mosaics of the work manage to coordinate actions on the order and cleanliness of the site (one of the main tools to reduce the risk of accidents) achieving better working conditions. The use by the UPM communications team has been extensive both to report to the company headquarters and to the community about the progress and impact of the project.	The use of drones allows better progress reports to be sent to the headquarters and generates higher quality information, facilitating project management and decision making. The company outsources the activity.

3. What is the level of adoption of drones in infrastructure and construction supervision in Latin America?

Figure 25 (2/5) Selected cases and experiences

PROJECT	DESCRIPTION	ACTIVITIES IN WHICH DRONES WERE USED	REPORTED BENEFITS	OTHER CONSIDERATIONS
National Road No. 1 Transportation Haiti 2014-2018	Supervision of the paving of National Route 1 of Haiti, between Gonnaives and Camp Coq. Inspection and supervision of the work tasks and administrative follow-up of the work contract. The route crosses a winding and rugged mountainous terrain, with few existing access points and with a dense vegetation cover of vulnerable biodiversity. Total amount of work: USD 90 million.	Evaluate construction progress. Recording of images for follow-up meetings, persuading the builder of good practices, especially environmental and social issues impacting the communities.	Drone evidence (i.e. images) provided objectivity in the context of situations of divergence of project stakeholders views on certain aspects of the construction. Example: the builder was dumping material on the side of the road, on the side of a mountain. It was a place that could not be seen with the naked eye and thanks to drone photos they were able to prove this situation and avoid further environmental damage.	The use of drones arises from a need to have **truthful and objective information**. The drone made it possible to monitor and measure the impact of the practices carried out by the executing companies, in addition to verifying compliance with the Bank's policies and safeguards. In addition, in the Ennery-Plaissance section, comparative pilots of topographic and volumetric monitoring were carried out with drones and with traditional systems to evaluate their precision and speed.
ADIF Transport Argentina 2015-17	Review of the executive project and inspection of the construction works of the new track infrastructure of the General Roca Railway in the Buenos Aires to Mar del Plata branch, for the Dolores sector (prog. Km. 199,000) to Maipú (prog. Km. 270,264), Buenos Aires province. Amount of work: USD 40 million. It was also applied in the review of the executive project and inspection of the renovation works of the track structure in the General Belgrano Railway - Section 1: Branch C, Km. 211,240 to Km. 275,479 - Province of Santa Fe, Argentina Review of the executive project and inspection of the renovation works of the track structure in the General Belgrano Railway - Section 2: Branch C, Km. 275,479 to Km. 338,010 - Province of Santa Fe, Argentina.	Stock control Workshop control.	Time saving for control of large piles of material: sleepers, rails.	The use of the drone arises from the need to **control materials that at first glance are difficult to count**.

3.
What is the level of adoption of drones in infrastructure and construction supervision in Latin America?

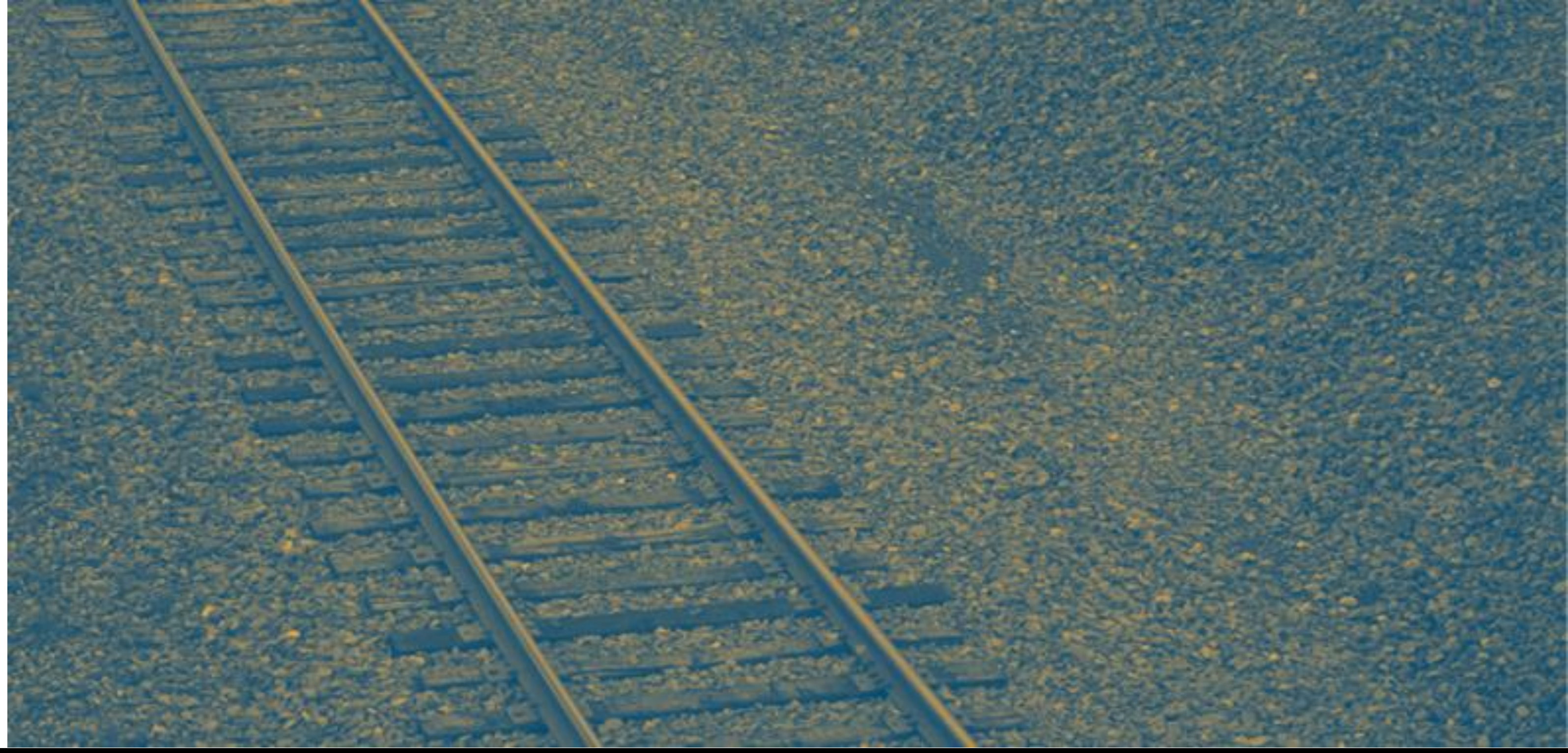


Figure 25 (3/5) Selected cases and experiences

PROJECT	DESCRIPTION	ACTIVITIES IN WHICH DRONES WERE USED	REPORTED BENEFITS	OTHER CONSIDERATIONS
Design of Road Corridor Transportation Argentina 2018	Design of new roads and maintenance works linked to corridors B and South of the Stage 1 tender under the PPP regime.	Topographic survey: Photogrammetry to carry out project engineering for which there was no basic information (engineering pre-designs).	The estimation is that the survey cost per km was lowered in the order of 50% - 60%, while sacrificing some level of precision. But it was also not for cost reasons that this technology was chosen but rather because of speed: a survey and post-processing can take 1-2 weeks (depending on the crew you must do it) to cover a few km, while with the drone it only takes days.	The use of the drone arises from **a need to carry out an expedited preliminary engineering project in a short period of time**, which was not possible otherwise. There is a tradeoff between time and quality.
Paseo del Bajo –Tramo B – Semi trinchera Transportation Argentina 2016-18	Execution of a North-South connection corridor in the Autonomous City of Buenos Aires of about 7 kilometers, starting from the connection of the Buenos Aires – La Plata Highway, to the south of the City, with the Illia Highway in the Retiro area.	Monitor work progress and traffic issues (damages in the queue, count delays). Record of images for follow-up meetings, persuade the builder of good practices.	Agility and accuracy of information. Improvement of project management.	One of the main limitations in the use of drones in this project was the need to have special permits to carry out the flights, due to the urban context.
Transmission lines – EPM Energy Colombia 2020-2021	Transmission line at 110 kilovolts San Lorenzo-Calizas II, 40 kilometers long. It required the installation of 78 towers.	Construction of the towers with the most difficult access and laying of the conductors.	Access to difficult areas with abundant vegetation. Worker safety improvements. Conservation of areas. Protection and minimise impacts to the natural wealth of the area.	To provide **protection and reduce environmental impact**, EPM laid the conductors using drones.

3.
What is the level of adoption of drones in infrastructure and construction supervision in Latin America?

Figure 25 (4/5) Selected cases and experiences

PROJECT	DESCRIPTION	ACTIVITIES IN WHICH DRONES WERE USED	REPORTED BENEFITS	OTHER CONSIDERATIONS
IDB App – Infradigital Platform Various sectors Regional 2019-present	Tool that stores data and allows online analysis of infrastructure projects in all sectors and by country. The georeferenced projects appear on the platform; it contains information on the contracts and information obtained in the field captured through various means (videos and photos from drones, Google Maps, Google Earth, photos taken from a car, etc.). It is not only a repository/registry, but it also allows analysis by crossing information.	Advance control and management. Remote supervision of a country's project portfolio. Security control and people counting.	Generates supervision/monitoring reports automatically, facilitating management. Supervision time was reduced by up to 80% with the use of this tool. Records serve as evidence against lawsuits and litigation. Remote control (especially important in a pandemic), which translates into transportation savings. Before the application of the tool, the IDB had 1 consultant who was going to verify once a month or every 15 days, now with the tool he only goes once every 6 – 12 months.	The videos and photography obtained with drones is one of the inputs used by the tool. Therefore, the benefits are not fully attributable to this technology. However, it does show how the **use of drones with adequate software generates savings in time and cost**. For the EGS group, drone video is more useful than camera video.
Highway La Paz – El Alto Transportation Bolivia 2016-2017	The scope of the project included the rehabilitation of the highway (50 km), the reconstruction of the drainage system, the renovation of electrical installations and the lighting system, the construction of bus stops, and signage improvements, among others.	Advance control and management. Remote monitoring.	Savings (not quantified) in the supervision team and in the control visits by the IDB. Improvement in quality and management efficiency. Early detection of problems. Detection of environmental issues which by other means were not visible. Improvement in communication to senior management about the progress of the project and in the team's ability to have an innovative and real-time supervision scheme	The use of the drone arises from **a need for supervision**, because the supervision team quit. The main difficulty was finding drone operators.

3.
What is the level of adoption of drones in infrastructure and construction supervision in Latin America?

Figure 25 (5/5) Selected cases and experiences

PROJECT	DESCRIPTION	ACTIVITIES IN WHICH DRONES WERE USED	REPORTED BENEFITS	OTHER CONSIDERATIONS
Lima Subway Transportation Peru 2015	Construction of 35 kilometers of metro (27 kilometers of Line 2 and 8 kilometers of Line 4) totally underground through a concession contract. Estimated investment amount of just over USD 5,800 millions (partly financed by the IDB).	Counting of market stalls that would be affected by the construction of the subway.	It allowed a quick and efficient count of the number of stalls and their size, to plan market relocation. Analysis of environmental issues.	The use of the drone arises based on the **need, to carry out an activity that would not otherwise be possible** (due to opposition from merchants and security issues).
Hospitals Social Argentina 2020	In response to the increase in COVID-19 cases, the Argentine Government launched the construction of twelve modular hospitals to expand their capacity (with a total of 1,200 beds), including intensive care areas, isolation rooms and other equipment necessary to treat patients. Total investment of USD 23 million.	Topographic surveys. Supervision during the work.	Reduction of the time of the topographical surveys: surveys of the twelve localities, with a total of more than 10,000m² in only three days. Generation of precise digital maps of the area to work, which were very useful to help improve planning, speed up execution and enable all parties involved to view updated information on the site, thus avoiding setbacks.	Drone technology was used due **to the urgency and the difficulties in moving people due to the COVID-19 pandemic**. Equipped with DJI Phantom 4 Pro and Mavic 2 Pro drones.
Natural gas terminal, transmission lines, and logistics shed Several Brazil	Several cases discussed in interviews with construction management and supervision companies with extensive experience in Brazil.	Progress of work and services executed, for use in project management. Aerial survey for measurements: earthworks. Visual inspections on building facades, detecting cracks.	Greater efficiency in management. Security issues. It serves as evidence against litigation. Agility of inspection, reduction of risks associated with the safety of workers, better productivity, access to places which are difficult to access. Previous mapping of critical areas, possibility of re-analysing without having to do the physical inspection again, reduction of risks associated with the safety of workers.	These were mentioned in the interviews by different construction management companies in Brazil as successful cases in the use of drones for **improving efficiency, productivity and safety**.

3.
What is the level of adoption of drones in infrastructure and construction supervision in Latin America?

Key considerations

As detailed before, the benefits reported by different relevant stakeholders in the use of drones in construction activities are varied.

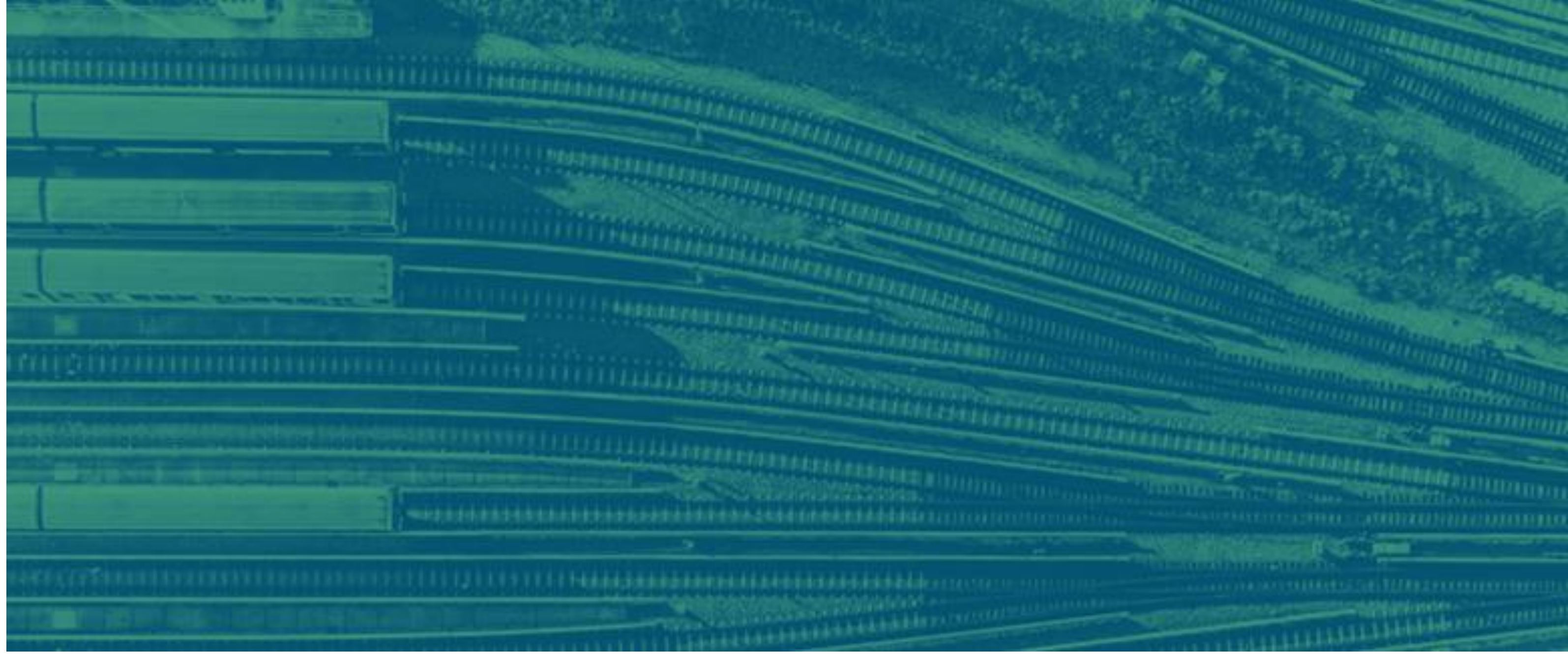
In terms of **time**, according to the PwC survey, **74% of respondents state that the use of drones allowed significant reductions in the project schedule, for instance, even 50% or more.** For example, in the case of certain monitoring activities of the Central Railway in Uruguay, a drone allows work to be completed **in a week, with which the conventional method would take around 15-20 days of work** (developed case in the next chapter). Another example is Route 1 in Haiti, where the interviewees indicated that the monitoring time was reduced **from 5 days by conventional means to 1-2 days with the use of drones**. The reduction in time is even greater if drone technology is combined with other technologies (for example, thanks to the App - Infradigital Platform, in some cases, interviewees indicated that the **reduction in time can be up to 80% depending on the project circumstances).**

This time reduction along with other factors (lower number of personnel needed to execute a task or an increase in productivity) also has its impact on **costs**. For example, the application of drones in the case of the Central Railway in Uruguay made it possible to reduce the team needed to monitor the progress of the work from **20 to 5 people**. According to PwC survey, **73% of respondents mentioned that the use of drones had an impact on cost reductions with different levels.** For example, in the preliminary design of a PPP highway in Argentina, the responsible engineering firm indicated that the use of drones for topographic surveys meant a **50-60% reduction in cost per km.**

In addition, as mentioned, there are other **qualitative benefits** that end up having an impact on the aforementioned variables (time/cost) such as improved information quality and greater objectivity, improved management processes and decision-making, increased productivity, reduction in the number of errors or their early detection, worker safety, evidence against litigation, care for the environment, among others.

Finally, it is worth mentioning cases in which the **activity could not have been carried out in another way**, either due to difficulties in accessing the area (due to vegetation in the case of the transmission lines in Colombia, or due to security, as in the case of Metro de Lima) or by the speed with which the development of the activity was required (case of hospitals in Argentina).

3.
What is the level of adoption of drones in infrastructure and construction supervision in Latin America?



CASE STUDY I

Central Railway

Sector	Transport (rail)
Country	Uruguay
Year	2019-present
Drone use	Internalised

Sector PUBLIC PRIVATE

3.2

Case Study Box: Overview of Selected Case Studies in Latin America

Project overview

Construction and maintenance of a railroad between the Port of Montevideo and the city of Paso de los Toros (273 km route), to enable the circulation of freight trains at 80 km/h and 22.5 ton/axle. The estimated project CAPEX was approximately USD 1 billion.

Project stakeholders and their experience in the use of drones

The Ministry of Transport and Public Works of Uruguay awarded the Grupo Vía Central (GVC) consortium the financing, design, construction, and maintenance of the Project in 2019, with a duration of 18 years. The GVC is led by Sacyr (40%) and other partners including Saceem (27%), NGE (27%), and Berkes (6%).

Sacyr is a large Spanish engineering and construction company that works in three segments: construction (development of large civil engineering, industrial, transport, and building infrastructure projects), infrastructure concessions (specialising in transport, sanitary, water, and waste treatment), and the provision of services. They are present in more than 20 countries (including Brazil, Chile, Colombia, Mexico, Paraguay, Peru, and Uruguay in LATAM), with more than 42,000 employees (2021 data).

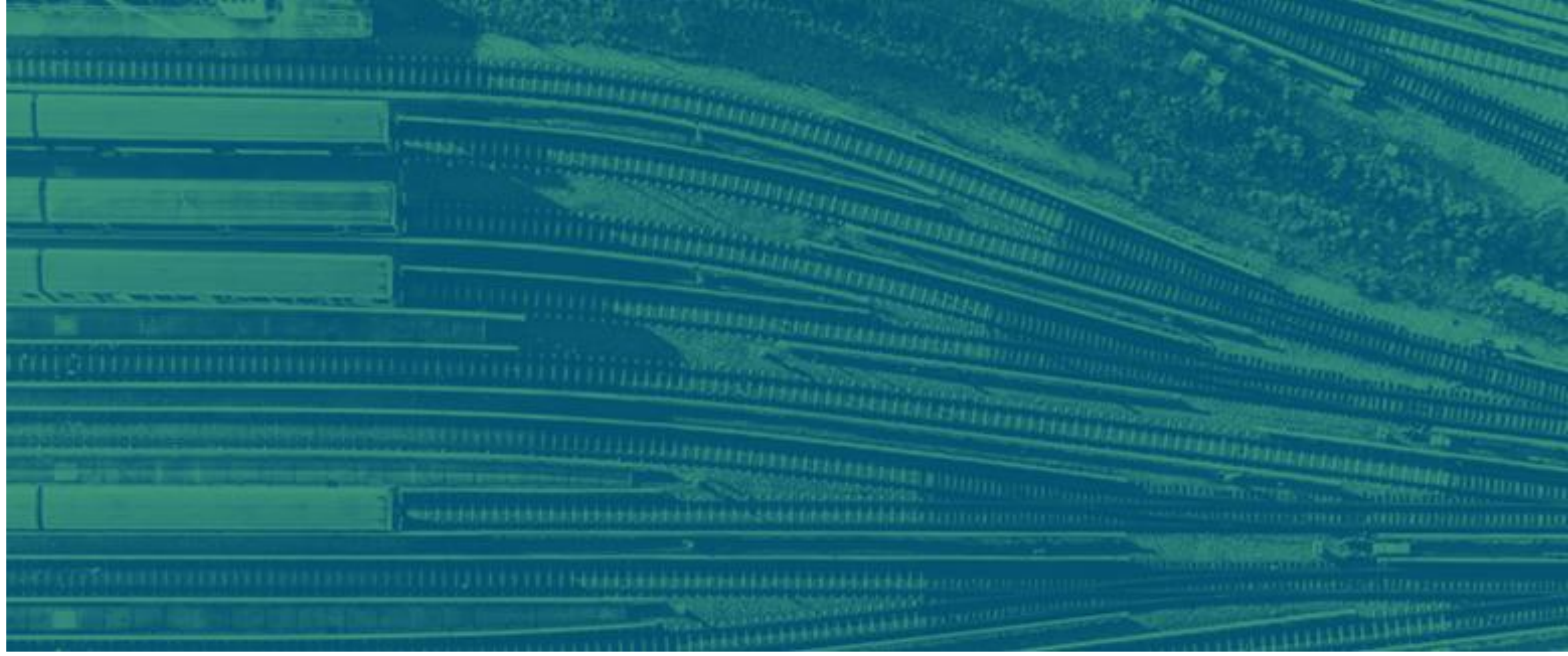
They have experience in the use of various technologies, especially drones, e-DMS, contracting and bidding process management tools, and BIM. Specifically, in the case of drones, the company has used them for the following purposes: project measurements and data collection (currently 27 teams flying in 7 countries: USA, Colombia, Uruguay, Brazil, Peru, Paraguay, Chile); documentary control (every month or every 15 days they make a "bird's eye view" flight for the company's management in order to detect deviations from what was planned, for future customer claims, litigation/ arbitration, and for rainy periods); and access to very complex sites.

They have incorporated drones in all their projects (regardless of the size of the project and in all countries), almost always carrying out the task in-house (eventually they subcontract it).

Currently, they mainly use small drones (less than 2 kg, DJI) with a high-resolution camera, made of plastic, with an autonomy of 20 - 25 minutes, and with a cost of about USD 3,000 - 4,000. They have a high accident rate (the useful life of each of the equipment is no more than 6-7 months).

In general terms, the main obstacle to its implementation in some cases has been government regulation, since the authorities of some countries are demanding to allow its use only through requiring permits that sometimes take time to obtain.

3.
What is the level of adoption of drones in infrastructure and construction supervision in Latin America?



CASE STUDY I

Central Railway

Sector	Transport (rail)
Country	Uruguay
Year	2019-present
Drone use	Internalised

Sector PUBLIC PRIVATE

Application of drones in the case of the Central Railway

In this project, between 4 and 6 drones are being flown for documentary control, "bird's eye view" for photography and monitoring, with internal implementation (both hardware and operators).

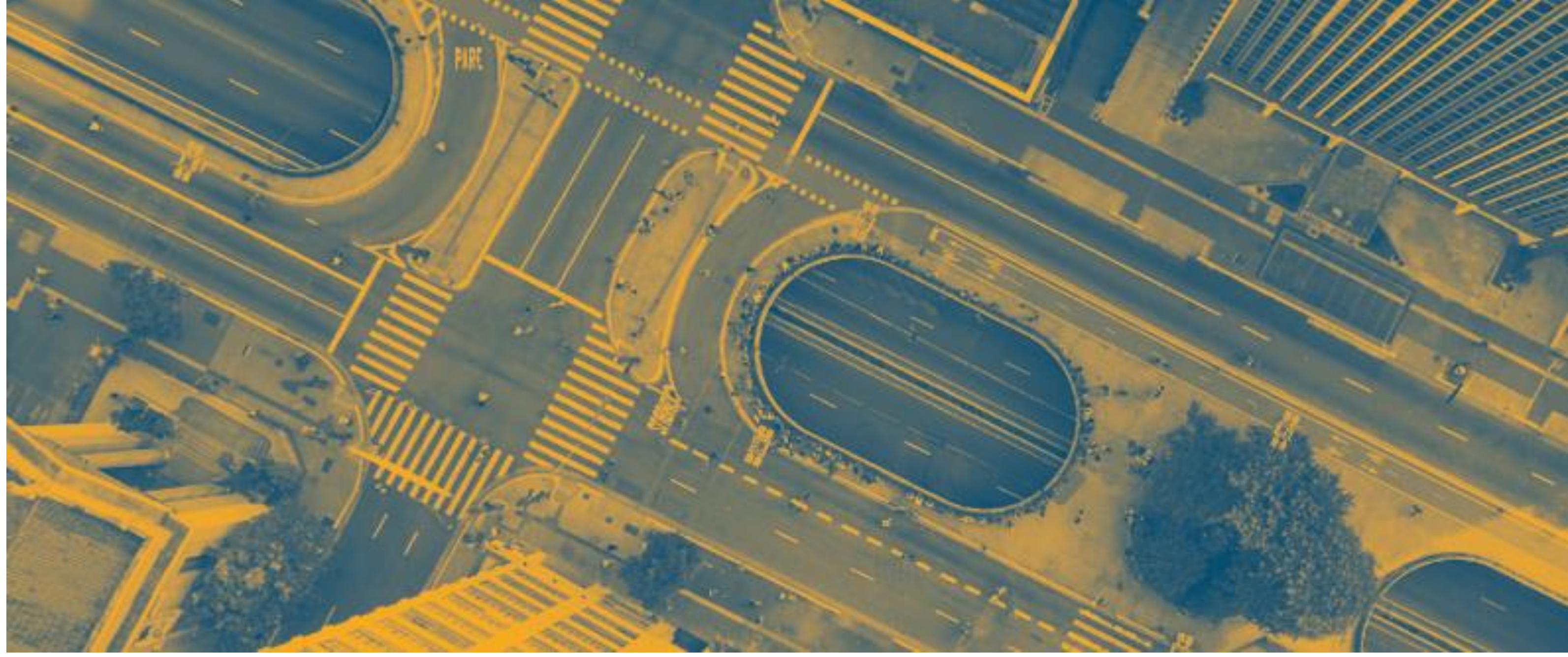
Benefits found from the use of drones in the activity

- Instead of visiting the construction site, the project director has a platform with a link and access to each week's flight. From Montevideo to Paso de los Toros there are about 5 hours of travel, which the construction manager can save for certain supervision instances.
- In a project with these characteristics, the conventional method would require around 20 people to carry out the work, while the application of drones allows that number to be reduced to 5 people.
- Regarding the time spent, what the drone application allows to do in a week, with the conventional method would take about 15-20 days of work.
- Use in adverse weather situations.

Sources:
Interview with Sacyr personal
https://www.gub.uy/ministerio-transporte-obras-publicas/ferrocarril-central
https://www.sacyr.com/-/ferrocarril-central
https://www.sacyr.com/-/sacyr-lidera-el-proyecto-mas-ambicioso-de-uruguay-el-ferrocarril-central

3.

What is the level of adoption of drones in infrastructure and construction supervision in Latin America?



CASE STUDY II

National Route 1

Sector	Transport (road)
Country	Haiti
Year	2017
Drone use	Outsourced
Sector	PUBLIC · PRIVATE · MULTILATERAL

3.2

Case Study Box: Overview of Selected Case Studies in Latin America

Project overview

This project involved the rehabilitation of National Route 1 (RN1), which connects Port-au-Prince with the port city of Cap Haitien. The work began in December 2015 for a total amount of USD 28.9 million (contract in the closing phase).

The project had several delays due to security issues and lack of fuel, which caused it to be stopped on several occasions. At the moment, around USD 20 million have been executed and the construction company selection process is once again underway.

At the end of 2017, in a pilot experiment, drones began to be used to monitor the physical progress of the Plaisance – Camp Coq highway (from a survey of spatial information) in a 10.8 km section. The products are high-resolution orthomosaics, which show the progress of the physical progress of the works in the execution phase, the calculation of volumes, and the monitoring of resettlements and affectations.

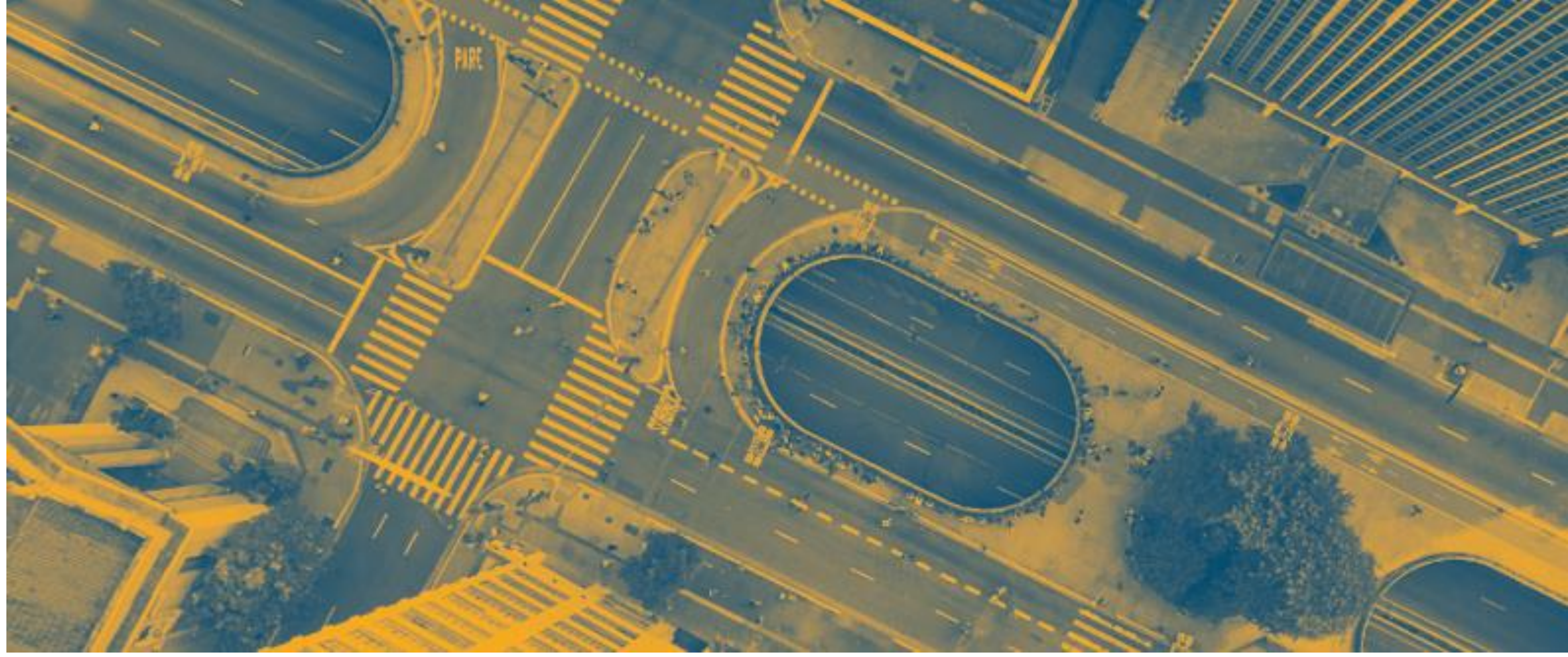
Related companies and their experience in the use of drones

AC&A was in charge of supervising the work. AC&A is a company specialised in providing engineering, architecture, and urban planning services and in carrying out environmental, economic, and planning studies. It was originally founded in Argentina and later expanded to several countries in Latin America. They have developed more than 190 projects in 30 countries around the world, with experience in the use of various technologies (e-DMS, BIM, 3D cost estimation software tools and BoQ development, among others). Regarding the use of drones, for site monitoring they use the smallest and most basic commercial drones from DJI (except in mountain conditions), and they fly them directly. For photogrammetry they contract the service with RTK drones (higher quality professional cameras and GPS) and small planes (AIRb). In the case of the project in question, Aeroterra was contracted directly by the IDB for the drone service (collection and subsequent processing of information). This Bolivian company specialises in aerial monitoring with drones and remote sensors integrated with GIS, with experience in agricultural activity, the environment, and the construction of civil works, among others.

Application of drones in the case of the RN1

To monitor the progress of the project, AC&A had a traditional supervision team (with topographers, laboratory technicians, inspection engineers, quality managers) and in parallel they put a team of drones out for 3 months doing photogrammetry to compare the volumetric results obtained by both methods.

3.
What is the level of adoption of drones in infrastructure and construction supervision in Latin America?



CASE STUDY II

National Route 1

Sector	Transport (road)
Country	Haiti
Year	2017
Drone use	Outsourced

Sector PUBLIC PRIVATE MULTILATERAL

To organise the flight of the drones, a mission planning process was first carried out. Based on the capabilities of the drone (flight time 20 minutes, signal range 4km) the parameters were established: flight height with respect to the ground 100-150m, pixel resolution less than 5cm GSD, overlap between photos 80% lateral and 60% longitudinal. Then the execution of the mission on the ground was carried out followed by photogrammetric processing, point cloud editing, and quality control. The costs associated with these activities were around USD 30,000 per monitoring (in total 6 were carried out: 1 baseline + 5 monitoring).

Benefits found from the use of drones in the activity

- Reduces time of the quantification process (activities that were done in 5 days by the conventional way are carried out in 1-2 days with the use of drones); with a very low difference in the results between the traditional way and the use of drones (the total volume variations ranged from 6.45% to 0.30%).
- More data was obtained during the month.
- Access to very difficult mountainous areas.
- The 3D model armed with the photos of the drone also made it possible to estimate the remaining cut volumes, providing advanced warnings of the possibility of additional cost overruns in the contract.

What was not detected was a saving in terms of the number of people needed in the work team. In projects of this scale (even those of 30-40 km), the same number of specialists is required because the vision of the expert is essential. For example, in this case there was a phase in which the material was obtained from the rock and dumped in an intermediate buffer, to later be taken to the final deposit (route embankment). When the drone flew over it, it identified the cut well, but then the intermediate step was identified as an embankment. So, the expert's opinion was necessary, stating that this was not an embankment and therefore should not be paid (because it is not one of the items in the contract). Given that, even when applying drones, the presence of at least one surveyor in the field is still essential and in this project a reduction in personnel costs was not verified. For larger projects, there will probably be a saving in terms of personnel, because the number of surveyors that must be integrated into the team will probably be reduced.

Therefore, as a conclusion of the pilot plan, it was concluded that the drones do work to control quantities and allow the activity to be carried out with greater speed (the savings would be in time and quality). As a limitation, it should be considered that a professional operator, flight plans, control points are required (adding complexity) and a surveyor is still needed (does not replace personnel) in small projects. Other additional difficulties are getting the client to value the drone since the technology can be expensive when the project is not large. For this reason, in some cases the supervising company in this project has used satellite images as an intermediate tool, which has a lower price and a lower quality (it is used to see the progress of the work in general, with little detail).

Source:
Interviews with the IDB and AC&A
https://blogs.iadb.org/transporte/es/el-guardian-de-cien-ojos/
AEROTERRA presentation on its monitoring methodology (April 2018)
Monitoring report (November 2018)

3.

What is the level of adoption of drones in infrastructure and construction supervision in Latin America?

CASE STUDY III

Girardota Industrial Quarry

Sector	Industrial (mine)
Country	Colombia
Year	2016
Drone use	Internalised

Sector PRIVATE

3.2

Case Study Box: Overview of selected case studies

Project overview

Industrial Conconcreto is a company in the Conconcreto business group that was born in 2011 with the aim of producing and marketing supplies for the construction sector through its four business units: Aggregates, Prefabricated and Durapanel.

Aggregates is the unit dedicated to the exploitation and commercialisation of stone materials used in the production of concrete. Industrial Conconcreto periodically extracts material from rivers (washed sand for concrete, crushed 1" and grit 3/8") from a mine in Girardota, Antioquia.

Related companies and their experience in the use of drones

The Colombian company Conconcreto, founded in 1961 and headquartered in Medellín, participates in the engineering and construction sectors. Its infrastructure division provides planning, design, construction, operation, and maintenance services for civil engineering projects such as tunnels, bridges, airports, hydroelectric plants, highways, and mass transportation systems; while its industry division encompasses distribution centers, warehouses, piers, and pipelines.

The Conconcreto Group has an Innovation and Digital Transformation division that provides support to the other units, and for this purpose, over the last decade, they have used different types of technology: BIM (the most used), drones, virtual reality, augmented reality, IoT, data analytics, etc.

Regarding drones, the innovation team began experimenting with this technology in 2016 through the acquisition of devices (different versions of Phantom up to the 4th) and their own personnel were in charge of operating it. After that, they continue to use drones (combined with other technologies) but outsourced the service to a specialised company. Thus, each project had an opportunity to choose the type of drone that best suits the job and can follow the advances in technology more efficiently. They have used drones in the supervision phase, in large surface projects, and for roads. They have also used this technology in the design phase (for example, with photos used later to execute the BIM model) and for commercial issues for clients.

3. What is the level of adoption of drones in infrastructure and construction supervision in Latin America?

CASE STUDY III

Girardota Industrial Quarry

Sector	Industrial (mine)
Country	Colombia
Year	2016
Drone use	Internalised

Sector PRIVATE

Application of drones in the case of the Girardota Industrial Quarry

Historically, the determination of the volumes was carried out by means of traditional topography. As a pilot test, in 2016 it was decided to use drones to carry out this activity and buy the results. The main objective in the use of this technology was aerial photogrammetry for the determination of the volumes of materials (for construction), areas, and distances in their aggregate mine.

Benefits found from the use of drones in the activity

- Greater precision in the determination of material volumes: a difference of around 4-5% was found between aerial photogrammetry and traditional measurement, with drone measurement having greater precision.
- Lower staff requirement. By the traditional method, the Topographic Commission was made up of a team of 3 or 4 people, while for the application of drones a single person is needed to fly the drone and then process the information.
- Time reduction. The drone application takes 20 minutes of overflight and information processing of 2 or 3 days, while with the conventional method it takes a week for survey and processing.
- Other benefits that they have found in general in the use of drones is being able to reach areas that are difficult to access, and in a safer way for workers.

Despite these advantages, they also ran into some limitations in the use of drones:

- Regulatory issues: mainly in the city, the regulations must be studied to see if the area to fly over is not close to an airport or within prohibited areas or areas that generate interference.
- Vertiginous advance in technology: the degree of advance that technology has led them to outsource the use of this technology since their own drones were becoming obsolete (unlike a company specialized in drones that can constantly renew its fleet to have the latest technology available and that the investment in said renovation deserves it).

Source:
Interview with Alejandra María Carmona Duque, Director of Innovation, Conconcreto

3.
What is the level of adoption of drones in infrastructure and construction supervision in Latin America?

3.4

Key barriers for the use of UAS in the construction sector in Latin America

Clients' unwillingness to pay for system implementation or the associated costs was identified as the main barrier to the implementation of drones. This becomes a major barrier when the project is not of a large scale. In larger projects, the relative cost of the drone is diluted in the total and this disadvantage becomes less important.

Difficulties around the adoption of technologies was mentioned in second place. Lack of knowledge in handling drones or subsequent information processing are major barriers in the implementation of this type of technology.

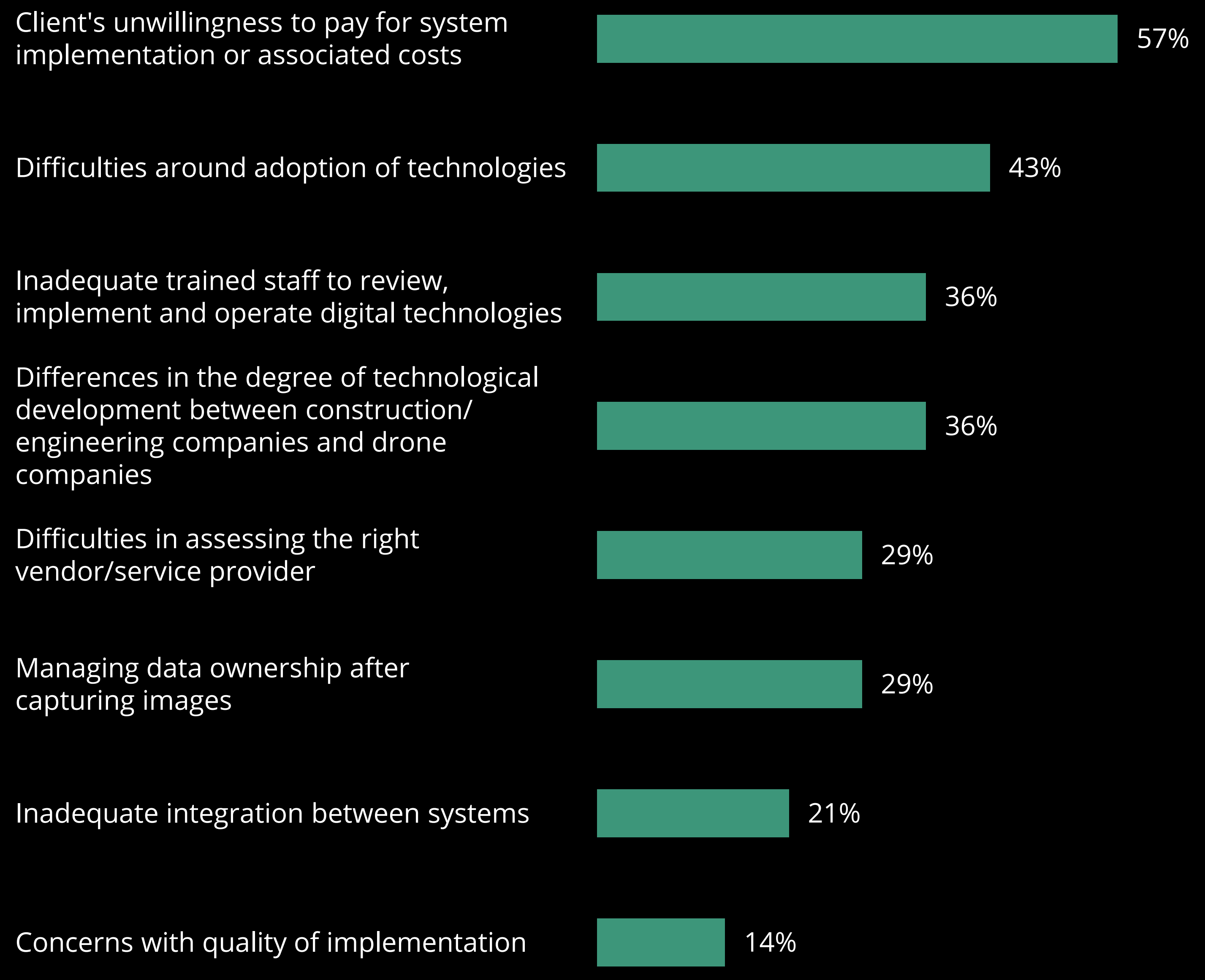
Another obstacle that is especially relevant in the countries of the region is the lack, scarcity or inadequate government regulation, since the authorities of some countries are demanding to allow its use only through requiring permits that sometimes take time. Obstacles in regulatory matters have been seen mainly in the city, where it is necessary to study the regulations to see if the area to fly over is not close to an airport or within prohibited areas or that generates interference.

Another barrier is the lack of incentives, either because the benefits are not clear, because the other stakeholders involved in the project do not use this technology, or because the client does not value (nor is willing to pay for) its application.

"The drones are in the pilot phase, therefore there are no conclusions to date."

"Digitalisation in the supervision and monitoring of road projects is lagging far behind, for fear of breaking traditional procedures and making transparent decisions that compromise sectors of power and decision-making."

Figure 26: Major concerns related to implementation of UAVs for projects monitoring and surveying



Question: Major concerns related to implementation of UAVs for project monitoring / high-definition surveying

Source: PwC Analysis

"More awareness is needed about their use, appropriate equipment prices, accessible data readings and/or reproduction software or what I would say friendly for download and implementation."

"The legislation for the use of drones grows day by day and in some places, it is very difficult to use drones, since flight permits take time to be issued by regulators, so they lose competitiveness."

4.

How can the adoption of drones and digital technologies be facilitated?

4.1

The key elements and components of digital transformation

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. Professional drone services are widely available across Latin American and Caribbean countries, and the entry barrier for purchasing drone hardware and software is also relatively low.

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.

Figure 27: Drone data lifecycle management

Data acquisition	Data processing	Data analysis	Data delivery	Data maintenance
Drone data acquisition and provisioning following requirements, standards, rules, and guidelines that leads to bringing the right data, to the right people.	Transformation, fusion, data processing into geospatial technical products in the right format and level of detail.	Leveraging available datasets and software for retrieval of information and improvement of decision-making processes.	Data delivery and visualisation using on-premises or cloud-based solutions to reach the key stakeholders and facilitate collaboration.	Definition of appropriate data storage, access, and integration policies to leverage the drone data.

Source: PwC Analysis

4.

How can the adoption of drones and digital technologies be facilitated?

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. Decision-makers – and all stakeholders – are able to use the data in relevant meetings to make decisions based on facts. 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.

Figure 28: Drone digital transformation dimensions

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

Source: PwC Analysis

Organisations considering the implementation of drone technologies on a large scale must consider multiple factors: defining the skills required; analyzing 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.

4.

How can the adoption of drones and digital technologies be facilitated?

4.2

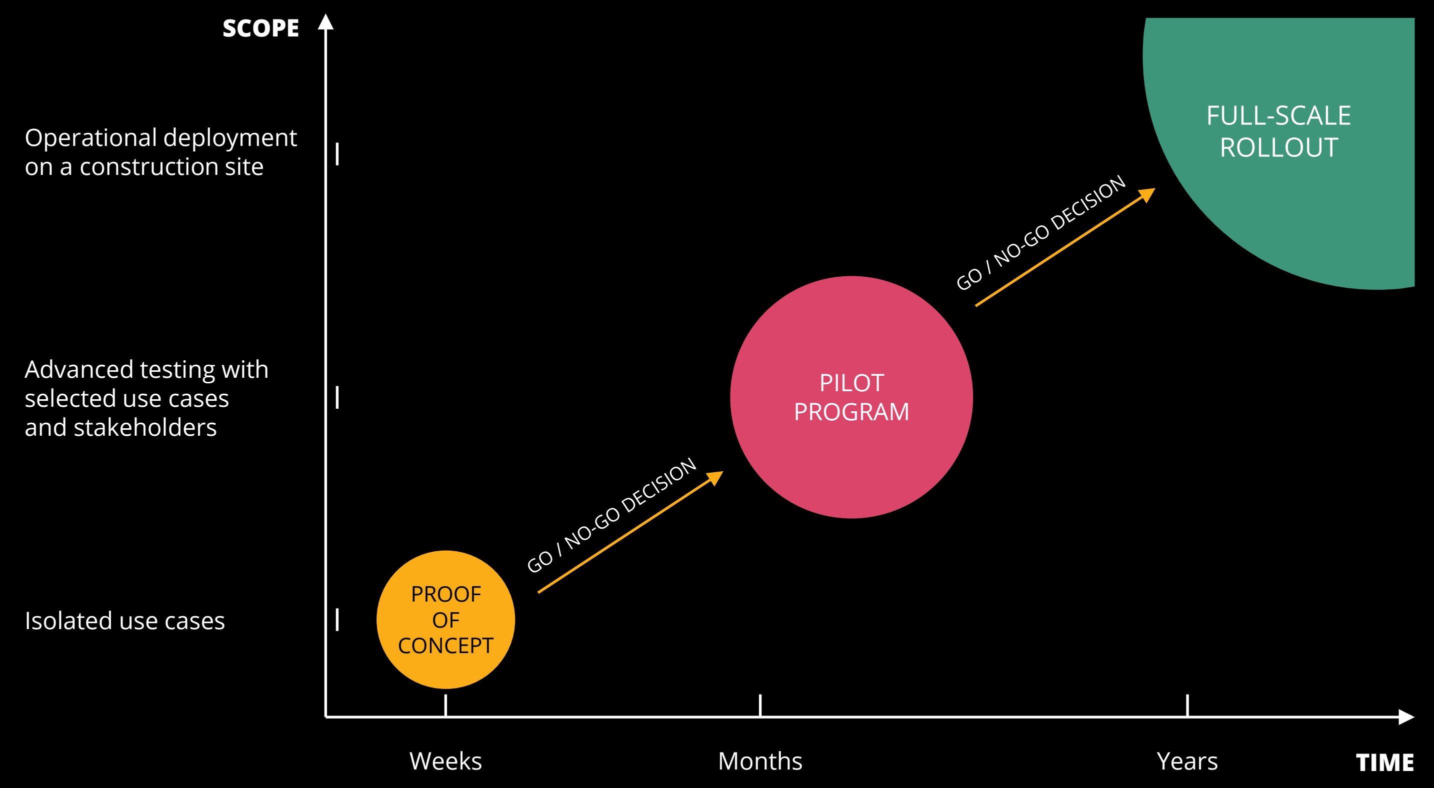
The adoption processes

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. PoCs are conducted with minimal effort and budget. Organisations might test multiple use cases within a single PoC or perform multiple PoCs for each relevant use case before assessing the feasibility of the technology for their operations. 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 centers 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 organisation.

Figure 29: Recommended model for drone solutions implementation



Source: PwC Analysis

Next steps

The importance of measuring benefits and supporting companies in the process of implementation

The digital transformation that comes with introducing 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 should be considered a critical requirement for all stakeholders.

To advance in this direction, it is essential to develop a **methodology for measuring benefits**, which allows direct (personnel, time) and indirect impacts (early error detection, material savings, fewer claims, fewer accidents, etc.) to be quantified. Adopting digital technologies is a long-term process, and related cost and time savings are often not directly visible in the construction budget. In some cases, the benefits are long-term and pertain to safety and risk avoidance, which are difficult to measure. This should be a point to consider.

This effort could be complemented by **a detailed guide (governance, procedures, etc.) on best practices to facilitate the implementation of drone solutions in construction projects**, and this handbook should consider the fact that the capture of benefits of drones grows significantly when it is used in conjunction with another complementary technological tool. There is no doubt that, in the future, drone data will be used to automatically track construction progress and adherence to design based on integration with CAD and BIM models and AI. Digital transformation brings an opportunity to redesign processes to remove inefficiencies and bottlenecks in the way that things are done today.

Implementation support should **address all actors involved in capital projects**. Only in this way will the UAV adoption be encouraged and truly useful since the data captured by drones will be understandable to all parties, and the communication will be more fluid and more straightforward.

Annex

PwC survey methodology

During May 2022, an online survey was developed with more than 100 respondents including key stakeholders in the construction and infrastructure industry in LATAM.

Of the responses obtained, according to the area where most of the business is conducted, 65% corresponded to construction/engineering companies, 20% to financers, and the remaining 15% to certifiers and project controllers.

Regarding the type of organisation, 78% belonged to the private sector, 7% to the public sector, and 15% to non-governmental organizations (including multilateral institutions).

Among those consulted, we had responses from companies, organizations and institutions that operate in various countries in the region (Argentina, Brazil, Bolivia, Colombia, Chile, Haiti, Honduras, Mexico, Panama, Peru, the Dominican Republic, Uruguay,) and at a global level.

Annex

Questionnaire for construction/engineering companies, project Controllers and certifiers

Question 1. Area where you conduct most of your business

Question 2. Type of organisation

Question 3. Typical delays in project schedule, in normal conditions, given the recent experience of your organisation

Question 4. Typical cost overruns in a project, in normal conditions, given the recent experience of your organisation

Question 5. Key challenges that are causing delays and cost overruns (execution-related challenges in order of relevance)

Question 6. Top digital solutions being implemented in your organisation for purposes of construction supervision and maturity level per solution (piloted and plan)

Question 7. Satisfaction score with solutions (for each option in question 5)

Question 8. If you have implemented drones, what has been the result in terms of time reduction in the supervision process during the construction phase? (according to your perception)

Question 9. If you have implemented drones, what has been the result in terms of time reduction in other phases (design & operation)? (according to your perception)

Question 10. If you have implemented drones, what has been the result in terms of cost reduction in the supervision process during the construction phase? (according to your perception)

Question 11. If you have implemented drones, what has been the result in terms of cost reduction in other phases (design & operation)? (according to your perception)

Question 12. In which fields drone technology contributes to cost reduction and time reduction of construction supervision? (take 3 most relevant)

Question 13. In which construction industry branch typically are you providing supervision

Question 14. What other benefits drive you to use drones?

Question 15. How are you planning to implement UAV technology in your organisation:

Question 16. Major concerns related to implementation of UAVs for project monitoring/high-definition surveying

Annex

Questionnaire for drone companies / drone service providers

Question 1. How many personnel does your company employ?

Question 2. What hardware do you apply for your services

Question 3. How many UAVs do you have at your disposal?

Question 4. What is the average price range of one flying unit:

Question 5. How many drone services do you provide to your clients annually?

Question 6. How long is your company operating on the market?

Question 7. How do you provide drone service for the construction industry?

Question 8. What services are mainly purchased by clients from the construction industry?

Question 9. What drone-made outputs mainly are delivered to clients from the construction industry?

Question 10. What proportion of construction industry customers have specific product requirements? (have an understanding of technical capacity and capabilities)

Question 11. What is the biggest barrier to the development of your drone products/services? (select 3)

Question 12. What in your opinion is currently the biggest obstacle to wider UAV service implementation in the construction?: (select 1)

Question 13. What is the estimated share of provided services to the construction sector compared to other industries combined (e.g. agriculture, mining)?

Question 14. In which sector the use of drones is in your opinion the most promising?

Question 15. How do you expect the level of demand for drone services in the following years for the construction industry?

Question 16. Are you planning to make an investment in your business in the coming year to increase value in the eyes of potential customers?

Annex

Questionnaire for project financiers

Question 1. Type of organisation

Question 2. Typical delays in a project, in normal conditions, given the recent experience in projects your organisation finance

Question 3. Typical cost overruns in a project, in normal conditions, given the recent experience in projects your organisation finance

Question 4. Key challenges that are causing delays and cost overruns (execution-related challenges in order of relevance)

Question 5. Top digital solutions currently being implemented in the projects being financed by your organisation for purposes of construction supervision and maturity level per solution

Question 6. If drones have been implemented in projects you have finance, what has been the result in terms of time reduction? (according to your perception)

Question 7. If drones have been implemented in projects you have finance, what has been the result in terms of cost reduction? (according to your perception)

Annex

Type of drones comparison table

	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		

Annex

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Glossary

BIM: Building Information Modeling
BVLOS: Beyond Visual Line of Sight
CAD: Computer Aided Design
DSLR: Digital Single Lens Reflex
LiDAR: Light Detection and Ranging
GNSS: Global Navigation Satellite System
GCP: Ground Control Points
RTK: Real-Time Kinematic
PPK: Post-Processing Kinematic
UAV: Unmanned Aerial Vehicle
UAS: Unmanned Aerial System
UTM: Unmanned Traffic Management
VTOL: Vertical Take-Off and Landing
CORS: Continuously Operating Reference Stations
SIRGAS: Pan-American organisation formed of regional Geodesy and Cartography, universities and research centers
CAGR: Compound annual growth rate
BoQ: Bill of Quantities
ERP: Enterprise resource planning
AR: Augmented Reality
IoT: Internet of Things
CDE: Common Data Environment
e-DMS: electronic Document Management System
SME: Small and Medium-sized Enterprises
UAV: Unmanned aerial vehicle

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