Skies Without Limits

v2.0

The potential to take the UK's economy to new heights

July 2022

pwc

A refreshed look at how drones could impact the UK's economy, jobs, productivity and quality of life

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Skies Without Limits v2.0

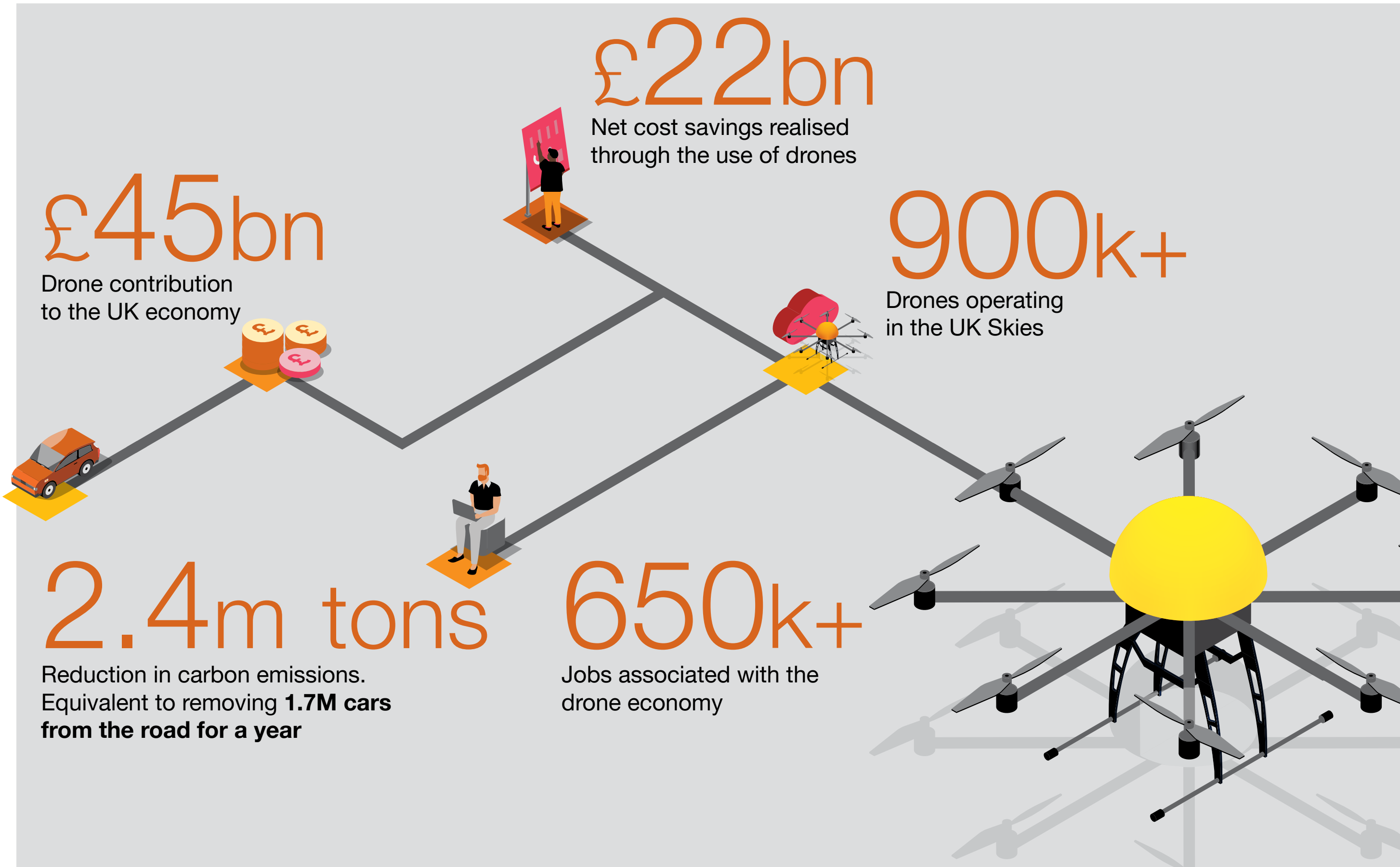
Drones have the potential to make a significant impact on UK productivity but there is much to do to realise this.

PwC's 2018 report "Skies Without Limits" (**SWL1**) described the potential for drones to positively impact the UK economy. Four years on, and in collaboration with the Department for Business, Energy and Industrial Strategy (BEIS) and Department for Transport (DfT), we have revisited the report.

Drones offer public and private organisations an opportunity to carry out tasks faster, safer, cheaper and with less impact on the environment than traditional methods. This report focuses on these types of drone operations, which we refer to as **"Commercial Drones"**, excluding drones used by hobbyists, drones used to transport passengers and counter-drone solutions.

This report builds on the **SWL1** report to assess the potential impact of drones on economic output, jobs and emissions. It uses a similar "best case" drone adoption curve to the **SWL1** report and, noting that many challenges must be addressed to unlock this potential, estimates that, by 2030:

- Drones could contribute up to £45bn to the UK economy
- More than 900,000 drones could operate in the UK's skies
- £22bn in net cost savings may be realised
- Carbon emissions could be reduced by 2.4M tons
- 650,000 jobs could be associated with an economy that fully adopts drones



Further detail on these figures can be found in the "UK 2030: The Updated Economic Impact" and "Methodology" sections below.

Cost Savings

The level of cost savings will vary between industries, with the *Public and Defence, Health and Education sector* considered to have the most significant potential for cost reductions, estimated at some £4.6bn by 2030. Other sectors including *Agriculture, Mining, Water, Gas and Electricity* and *Transport and Logistics* also have the potential to deliver significant savings.

CO2

Drones are better for the environment than "traditional" approaches. The combination of cleaner power and speed of data capture replaces vehicles in some sectors and reduces vehicle use in others. We estimate that, by 2030, drones could deliver a carbon reduction of 2.4M tons of CO2e, equivalent to taking around 1.7M diesel cars off the road for a year.

GDP Impact

Cost reductions combined with efficiency improvements from drone usage can help the UK economy address its long-term productivity challenge, as recently set out in Build Back Better: our plan for growth. These estimated savings could generate considerable GDP uplifts when compared to a scenario where drones are not adopted. Examples include £14.1bn GDP uplift in *Public and Defence, Health and Education*; £13.3bn in *Wholesale, Retail Trade, Accommodation and Food Services*; and £7.0bn in *Financial, Insurance, Professional and Administrative Services*.

Number of Drones

We expect a significant increase in the number of drones in UK airspace as entities invest to realise savings from drone adoption. Of the up to 900,000 drones that could be flying across UK skies by 2030, over a fifth (21%) could be used by the *Public and Defence, Health and Education* sector, contributing to a safer UK and enabling these sectors to embrace the range of benefits associated with drone digital transformation.

Jobs

The impact on jobs could be substantial and we estimate that, by 2030, around 650,000 full time equivalent workers in the UK could benefit from drone adoption. Our modelling does not suggest that these will be net additional jobs, but jobs where significant role changes will occur in the process of drone adoption. The combination of drones and automation may initially lead to some posts becoming redundant but, over time, the gains in cost savings and productivity generated by drones will transform how we work and live and lead to significant new employment opportunities for those that are willing to retrain.

Other Impacts

Drones are usually safer than traditional approaches, particularly when working at height (which tops the list of work-related fatal injuries). They also offer a range of other societal and environmental benefits. Drones are often thought of as portable sensors and PwC's reports "Fourth Industrial Revolution for the Earth" and "Exploring 4IR-enabled applications for the SDGs" consider that drones are a key part of the Fourth Industrial Revolution ("4IR"), assist with sustainability and help fight climate change. For example, drones can be used to capture data that informs water security, ocean health, reforestation, conservation of species, protection of habitats and disaster resilience.

> “We expect a significant increase in the number of drones in UK airspace as entities invest to realise savings from drone adoption.

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Unlocking Drone Potential

Our headline figures show the exciting transformational potential of **Commercial Drones**. However, as noted in **SWL1**, there are ***"many challenges to overcome to unlock the real potential of drones in the UK"***. These include **Public** and **Industry Perception**, the manner of drone implementation, technology, regulation and skills. These challenges are often linked; for example, more advanced technology may reduce the risk the regulator attaches to certain drone operations, enabling routine approval that is not possible with current technology. We discuss each of these challenges below, including links to the report's case studies which feature exciting, real-world examples of UK drone implementation. We assume that commercial matters such as insurance and nascent drone service commercial models (e.g. **UTM**) will not be a barrier to growth. Recommendations on how to address these challenges are not in scope for this report.

Perception

Although many thought that negative **Public Perception** could limit the adoption of drone technology, to date, it has not been a significant barrier to growth in **Commercial Drone** applications such as **Inspection** and **Survey**. **Public Perception** is likely to be a much more significant point when **Last Mile Delivery** of parcels and food starts to gain momentum and, to a lesser extent, when **Drone-in-a-Box** use cases such as security monitoring emerge.

A recent study from Project XCelerate considered that "we are at a tipping point in the **Public Perception** of drones". When asked about their attitude to increasing drone use in the UK and future drone applications, 49% of respondents were optimistic or positive about drones with as many as 39% pessimistic or concerned. We also note that in the DfT's Attitude Tracker (December 2021) "Two-thirds of people (67%) said, unprompted, they had at least one concern about the use of drones". It is possible that this is fear of the unknown. In contrast to the XCelerate study and DfT Tracker, we note that both in our **Last Mile Delivery** in Ireland Case Study (below) and in this study from Virginia Tech in the USA, communities that have actually experienced **Last Mile Delivery** from drones are positive about the experience.

Industry Perception is a major factor in the pace of drone adoption in the private and public sectors. Drone service providers and organisations with internal drone teams confirm that, even with **Commercial Drone** solutions nominally proven, there is still a lack of awareness and/ or a degree of reticence which prevents adoption at scale.

PwC's **Trust in Drones Survey** found that Industry (senior business decision makers in sectors likely to see increased drone usage) expected drones to deliver benefits in terms of:

- Time (78%)
- Safety (77%)
- Productivity (76%)
- Digital transformation (76%)

However, only one third of respondents agreed with the statement that "drones have been embraced by my industry and are used effectively." Issues included:

- Poorly articulated drone use cases (53%)
- Lack of service providers with a credible offering (52%)
- Lack of clear, compelling evidence of specific benefits has slowed adoption (50%)

We also consider that the manner of "Drone Implementation" has impacted **Industry Perception** and slowed the pace of implementation and cover this in the next section.

In contrast to these perception challenges, **Public Perception** and **Industry Perception** is strongly positive when it comes to the use of drones by emergency services, for medical delivery and other public "drones for good" use cases (refer to the PwC, DfT and XCelerate studies referenced above). In the "Sector Review and Case Studies" section below, we highlight a number of instances where drones in these sectors are saving money and saving lives today.

Drone Implementation

Our analysis shows that drone use in a wide range of sectors can be faster, safer, cheaper and better for the environment than existing methods. For example, drones are quieter and less polluting than helicopters, less risky than rope access or working in confined spaces and faster than ground-based land survey. They have become essential tools for many businesses in the UK but, in many cases, not all potential benefits are realised due to the drone implementation approach.

In early 2022, the majority of drone use is for **Inspection** and **Survey**. Until **Last Mile Delivery** drones and other "physical" applications take hold, the critical thing for **Commercial Drone** solutions is that they convert captured data into actionable management information that meets the precise requirements of the organisation.

Simply flying a drone, capturing sensor data such as images and even processing this into 2D and 3D models is not enough to realise the potential of drone-powered solutions. Drone information must be fit-for-purpose and integrated with business-as-usual workflows and IT systems.

One of the issues with implementing drones in an organisation is that the implementation is often considered "box ticked" when a vendor is selected or pilots are trained and drones are purchased – but this is only part of the story and, arguably, the easiest part. Effective drone implementations require a disciplined focus on capturing data that is of the appropriate quality, processing this data into actionable information that meets or exceeds existing information requirements, intuitively sharing the information with all stakeholders and integrating it with business as usual. In other words, effective drone implementation is not about buying services, training pilots and buying kit, it's about engaging all relevant stakeholders in a change programme. We cover this in more detail in the Cyberhawk/ Dronecloud (Data) case study below.

> "Drone information must be fit-for-purpose and integrated with business-as-usual workflows and IT systems

Technology

Drones are at the cutting edge of robotics and **AI**, powered by advances in materials, communications software and battery life. For example, some current commercially available drones have "full" **Autonomy** and create real-time 3D maps of their environment and dynamically navigate without any pilot input. To realise the projections in this report, a technology ecosystem that functions effectively for all drones from the most basic to the most advanced is required.

There are differing views on whether drone technology is limiting adoption.

Some consider that the implementation of existing drone technology is just too complex for most organisations. Not only do these organisations have to figure out how to select a vendor and/ or how to fly safely and legally, they must also deal with the volume of data captured, including integrating it with existing systems.

There is also a view that much of the drone technology required to realise the potential for drone productivity benefits is already here, proven in trials, and that the limiting factor is the approach taken in the UK, compared to other countries.

> "Drones are at the cutting edge of robotics and AI, powered by advances in materials, communications software and battery life.

Many of the technology building blocks for growth have already been demonstrated in the UK, to a greater or lesser degree. If we take a high-level view, we see four categories of technology required to realise the projections in this report:

- **UTM** (Unmanned Traffic Management) fully integrated with manned traffic management and capable of dealing with the significant increase in traffic volume associated with adding drones to the already busy skies, considered to include **Electronic Conspicuity** (refer to the Open Access **UTM** Framework published by the Connected Places Catapult and to CAP1868, A Unified Approach to the Introduction of UAS Traffic Management).
- **Detect and Avoid** to ensure that drones are "smart" and can avoid crashing into obstacles or other air users, whether through onboard capability, through **UTM** or a combination (refer to CAP1861a and associated sandbox challenge CAP2238)
- **Autonomy** beyond the implied autonomy in the "Detect and Avoid" point above, ability to safely fly complete missions without constant, "1 to 1" pilot input.
- **Infrastructure (digital and physical)** including high bandwidth and low latency communications to ensure safe and effective drones operations and take off, landing and charging facilities for certain use cases.

Each of these "blocks" would drive productivity benefits in their own right but all are ultimately required to realise the projections in this report. Note that this list is not exhaustive and associated technology developments such as propulsion (e.g. batteries, fuel cells), sensors, drone swarming, drones that can "touch" to sample or carry out repairs, etc are also likely to play a part in the growth of the UK drone economy.

Legislation and Regulation

In the **SWL1** report we stated that:

"For the projections in this report to be realised, the current regulations must evolve to allow further drone use cases. The UK Government is committed to remain at the forefront of the global drones market so that the economic potential can be realised, whilst prioritising the safety and security of UK citizens."

This is as true today as then and regulators all over the world are rising to the challenge. In the UK, airspace is more crowded than most and, while we must be aware of and continue to influence global regulatory development, it is key that our policy, legislation and regulation reflects UK-specific needs.

Regulation is often cited as the reason for a lack of progress in the adoption of new technology which appears to have proven benefits, and this is certainly the case with drones. We note above that developments in technology may have a significant impact on regulation, for example advances in technology may reduce the risk associated with certain operations and accelerate regulatory change.

While legislation, regulation and the implied attitude to risk does have to change to realise the full range of benefits stated in this report, this is not the whole story. It is important to note that many of the benefits associated with **Inspection** and **Survey** can be realised within the existing regulatory framework using a **VLOS** (Visual Line of Sight) drone solution, if implementation is effective and drone-captured information is seamlessly integrated with business as usual.

The evolution of regulations to allow **Routine BVLOS** (Beyond Visual Line of Sight) flight in **Unsegregated Airspace** is, however, key to maximise growth and we note that "Legislation/ Regulation" was the most frequent response to a "barriers to growth" question we posed to the case study companies in the fourth section of this report.

Routine BVLOS may improve the economics of an already compelling inspection and/ or survey use case, for example, refer to the **Future Flight Challenge Report** powerline inspection use case where **BVLOS** was 34% cheaper than **VLOS** drone inspection.

There is also significant potential for use cases which, in the main, require **Routine BVLOS** such as **Last Mile Delivery** of food and parcels with our estimates placing the Total Addressable Market at a combined £10bn in the UK, with virtually zero realised at present. The Manna **(Last Mile Delivery)** case study below shows the first steps taken to capture the market opportunity in Ireland.

Certain countries such as Australia (Wing) and France (Azure) have made progress on **Routine BVLOS** flights for **Last Mile Delivery** and **Drone-in-a-Box** and are closer than the UK to realising the economic potential of these solutions. These countries do not have an integrated **UTM** system and the technology maturity in areas such as **Electronic Conspicuity, Detect and Avoid, Drone Autonomy** and communications infrastructure, is not significantly, if at all, different from that available to UK entities. It appears that the Regulators in these countries have concluded that the risk of **Routine BVLOS** flights is outweighed by the benefits, even with existing technology.

There are encouraging initiatives in the UK, such as the **CAA's** Innovation Hub "sandbox" which aims to actively engage and team with drone innovators, rather than the usual regulator approach of "observing". You can find examples of the success of this programme in the Case Study section such as sees.ai (**BVLOS** remote inspection, CAA) and Flylogix (**BVLOS** methane sensing, CAA), both of which have either flown or are about to fly **Routine BVLOS** in **Unsegregated Airspace**. The **Future Flight Challenge** is also active in this area and is well positioned to accelerate the commercialisation of use cases that rely on **Routine BVLOS**, for example Phase 2 (Strand 1) projects such as Project Rise (**UTM** Integration), INMED (medical delivery including infrastructure), Swarm Technology and Digital Twinning (Windracers, Distributed Avionics, University of Bristol), SHIMANO (System for High Integrity Monitoring of Advanced-Air-Mobility Network Operations) and FUSE (Future Urban Simulation Environment).

BVLOS, however, remains "largely experimental" (Regulatory Horizons Council) and quite some distance from the **Routine BVLOS** required to unlock the projections in this report. It is also noted that the existing process for obtaining **BVLOS** permission is time consuming and there are opportunities for the **CAA** to increase automation and resourcing in this area.

In addition to the regulation of drone flight and associated regulation to address factors such as drone noise, there are other regulatory changes required to realise the potential of drones. For example, there is considerable potential for drones to be used in agriculture and forestry applications which could be realised were it permissible to seed or spray pesticide from drones. Our research indicates that the latter can reduce pesticide use by 30%+, compared to traditional methods; refer to the Drone Ag/ Auto Spray Systems (Agriculture) case study below. Another example could be the regulation associated with urban planning for drone infrastructure in cities.

Skills

To unlock the opportunities illustrated in this report, we need a new generation of entrepreneurs and engineers with the vision to develop and deliver innovative **Commercial Drone** solutions, refer also to the government's Plan for Jobs 2020. It is also important that potential end-users are aware of and receptive to drone solutions and including this topic in CPD (Continuous Professional Development) programmes may assist with this. We note that the UK generally performs well on innovation (4th in the Global Innovation Index 2021) but less well when it comes to diffusion of knowledge (11th). The OECD found that a better diffusion of technology from leaders which brought laggards to the median could increase aggregate productivity by roughly 6%.

Can aviation entrepreneurs flourish in the UK? There are certainly some encouraging initiatives such as the **Future Flight Challenge**. This initiative aims, amongst other things, to facilitate and fund collaborations between innovative startups and more established companies (both suppliers and end-users) to further the UK's future aviation technology offering by addressing technical and regulatory barriers to growth.

In addition to visionary entrepreneurs, the **Commercial Drone** industry will require a diverse range of vocational and academic skills if it hopes to realise the potential of the market. Examples of vocational skills could include piloting and maintenance. On the academic side, examples include many of the engineering disciplines, from aeronautical engineering to software. Finding these resources will not be easy due to the widely acknowledged shortages in the UK's STEM (Science, Technology, Engineering and Mathematics) pipeline, estimated at a 173,000 shortfall in 2022.

To compete for scarce STEM resources, the **Commercial Drone** industry should be clear on what it requires and take steps to differentiate itself.

An example of the former is the development of drone specific training and qualifications, which are likely to differ across market sectors. We note that more than 50% of respondents to our **Trust in Drones Survey** agree that industry-specific qualifications would lead to more adoption. This was also a clear finding from BEIS "end user" workshops held in November and December 2021. A structured method of assessing competence against the qualifications held is also critical. We consider that benchmarking other industries for qualifications and career path structure is desirable, for example the approach used by the PCN (Personnel Certification in Non-Destructive Testing).

Finally, the **Commercial Drone** industry should consider what sets it apart from other exciting new technologies and ensure that this is cohesively messaged to the target population, which could include reskilling and upskilling experienced employees.

3
UK 2030: The updated economic impact

In this report we update our earlier estimates of the impact of drones on the UK economy. We use the same overall approach, refined to reflect the changes in economic conditions since 2018 and to increase market sector granularity.

Our key findings are:

Drones will save businesses an estimated **£22bn** a year by 2030 and contribute **£45bn** to the UK economy. This is equivalent to **1.6%** of projected 2030 GDP.

By 2030 there will be **270,000** jobs associated with drone adoption. Across the whole economy there could be **650,000** jobs that will be positively affected by the benefits that drones can bring.

The GDP and jobs figures take account of the creation and destruction of some activities, and the shifting of others between sectors. In this context our GDP and jobs estimates are 'net' (after substitution and displacement effects) and in line with the UK Government's appraisal guidance, HM Treasury's 'Green Book' (page 92).

The UK economy has changed significantly since the 2018 report was written. This has led us to revise the baseline assumptions that underpin our economic model. In the 2018 report we assumed that GDP and wages grew in line with the Office for Budget Responsibility's long term GDP growth rate assumptions and assumed 1.5% per annum between 2017 and 2030, based on their 2017 to 2022 forecast. Such an assumption is standard in economic models of this type.

However, as we have all experienced, between 2020 and 2021 the economy suffered a significant negative economic shock as a result of the COVID 19 pandemic. This means the assumptions we made about the long term growth rate are no longer valid for these years.

One consequence of this negative shock is that overall investment suffered (noting that certain types remained buoyant such as R&D), resulting in less capital growth in the economy – meaning in future years the capital stock is smaller and the level of GDP is lower than it otherwise would have been. The knock on effect of this is that average incomes, savings and household consumption will be lower over the period 2021-2030 (the time periods covered in this report) vs. 2018-2030 (the time periods covered in our previous report). In addition, businesses will have lower average profits and this affects investment in future years. In essence, the economic effects of the COVID pandemic are not just felt in 2020/21, there is a degree of longer lasting scarring effect on the economy.

From the perspective of drones, this has a shrinking effect on the available market in which they can operate and on the profitability of drone operations. In an economy that has been structurally weakened, the economic benefits of each individual drone adoption are smaller.

However, a countervailing factor is that many larger businesses are experiencing lower corporate borrowing costs due to abundance of available capital (in part due to many businesses cutting investment due to COVID uncertainty). This could make drones cheaper to adopt. However, not all businesses are experiencing this, many smaller and medium-sized businesses are experiencing higher borrowing costs. This makes investment in new transformational technologies such as drones more challenging.

The second key assumption we have updated in this report is the real costs of labour, which, in recent months, have risen sharply in certain sectors of the economy as a result of both the COVID crisis and the UK's decision to leave the EU. In line with Office for National Statistics data and our own projections, we would expect these rising costs to manifest themselves in higher than average wage growth until 2024 for a number of key occupations e.g. transport and logistics. This has the effect of significantly increasing the cost savings that businesses can achieve through drone adoption.

The implication of both of these assumptions is that the need for drone adoption is now paramount more than ever. Businesses faced with smaller markets and higher operating costs will benefit more from new technologies, such as drones, that can help bring significant cost savings.

Finally, it is important to note that the figures we present show the "potential size of the economic prize". We cannot definitively say whether these figures will be net additional to our baseline forecast of average GDP growth from 2022 to 2030 of 2% per annum or just part of it. This is because our forecast is compiled from a range of independent long term forecasts of UK economic growth and it is impossible to tell the extent to which drones have been factored in or not.

> "The need for drone adoption is now paramount more than ever.

Cost Savings

Table 1 presents our estimated cost savings associated with drone adoption by 2030. The largest cost savings are again associated with the *Public and Defence, Health and Education* sector (£4.6bn), but there are also significant cost savings associated with *Agriculture, Mining, Water, Gas and Electricity* (£4.4bn) and *Transport and Logistics* (£4.2bn).

In the case of the *Agriculture, Mining, Water, Gas and Electricity and Transport and Logistics* sectors the projected 2030 GDP gains are smaller than the cost savings. This does not mean that drone adoption is inefficient for these sectors, ultimately sectoral contribution to overall GDP is still growing. Our modelling suggests that cost savings do not translate fully into GDP gains in sectors where businesses do not necessarily serve consumers directly, experience high levels of competition, lower levels of average business profitability or lower than average wages.

Our modelling also suggests that such sectors may benefit other sectors through a loss of skilled workers who are attracted by higher wages.

Overall, drones are more efficient than “traditional” approaches and have the potential generate a significant cost saving of £22Bn by 2030, assuming a similar “best case” drone adoption curve to the **SWL1** report and noting that many challenges must be addressed to unlock this potential (refer to the “Unlocking Drone Potential” section above).

Table 1: **Cost savings associated with drone adoption by industrial sector in 2030. All figures expressed in 2021 prices.**

Industry Sector	Cost Savings £bn	Cost Savings % of 2030 GDP
Public and Defence, Health and Education	4.6	0.9%
Agriculture, Mining, Water, Gas and Electricity	4.4	3.5%
Transport and Logistics	4.2	3.5%
Wholesale, Retail Trade, Accommodation and Food Service	3.7	0.7%
Financial, Insurance, Professional and Administrative Services	3.0	0.3%
Construction and Manufacturing	1.6	0.4%
Technology, Media and Telecommunications	0.9	0.4%
Total	**22.4**	**0.8%**

GDP Impact

Table 2 shows the impact of drone adoption across seven industrial sectors. The *Public and Defence, Health and Education; Agriculture, Mining, Water, Gas and Electricity* and *Transport and Logistics* sectors are expected to see the largest gains in monetary terms. This represents a significant percentage in the smaller *Agriculture, Mining, Water, Gas and Electricity* and *Transport and Logistics* sectors which are at 3.5% with all other sectors below 1%.

In our modelling exercise all seven industry sectors will gain economically from the adoption of drones.

The businesses that benefit most from a GDP perspective are the ones that are able to adopt and capitalise on the cost savings associated with drones more quickly than their competitors and in turn reinvest those cost savings whether that be in more drone related technologies or other business priorities. The stronger the competitive landscape within an industrial sector, the greater the imperative from the perspective of a first mover advantage.

Table 2: **Impact of Drones adoption on GDP by industrial sector in 2030. All figures expressed in 2021 prices.**

	GDP Impact	
Industry Sector	**£bn**	**% of 2030 GDP**
Public and Defence, Health and Education	14.1	2.6%
Wholesale, Retail Trade, Accommodation and Food Services	13.3	2.4%
Financial, Insurance, Professional and Administrative Services	7.0	0.7%
Agriculture, Mining, Water, Gas and Electricity	3.0	2.4%
Transport and Logistics	2.8	2.3%
Construction and Manufacturing	2.8	0.6%
Technology, Media and Telecommunications	2.4	1.2%
Total	**45.4**	**1.6%**

Table 3: **Projected number of Commercial Drones by industrial sector in 2030.**

Industrial Sector	'000 Drones
Public and Defence, Health and Education	202
Agriculture, Mining, Water, Gas and Electricity	182
Transport and Logistics	171
Wholesale, Retail Trade, Accommodation and Food Services	142
Financial, Insurance, Professional and Administrative Services	125
Construction and Manufacturing	65
Technology, Media and Telecommunications	36
Total	923

Jobs

Our analysis of the impact of drones on jobs strongly suggests that drone adoption will enhance workforce productivity and most likely create new roles associated with drone operation. The roles will be wide-ranging, from drone operators and maintenance teams to airspace regulators and software engineers.

In line with the GDP analysis, our modelling does not suggest that these will be net additional jobs, but jobs where significant role changes will occur in the process of drone adoption.

We estimate that 270,000 jobs could be directly affected. The bulk of these job changes will be in the *Public and Defence, Health and Education* and *Wholesale, Retail Trade, Accommodation and Food Services* sectors. Given that our modelling suggests that drone adoption will contribute positively to GDP and create more economic activity we would expect that the impact on overall job creation would at worst be neutral and at best be positive. However, drone adoption will augment people's jobs, roles will change significantly and businesses will need to train their workforce in how to use and maximise the benefits of drone adoption. These figures capture the net effects of these changes but, in reality, some workers may lose their jobs to a drone and other workers with different skills might be brought in to replace them.

Our modelling is not able to capture the winners and losers at an individual level, only the whole economy aggregate effect.

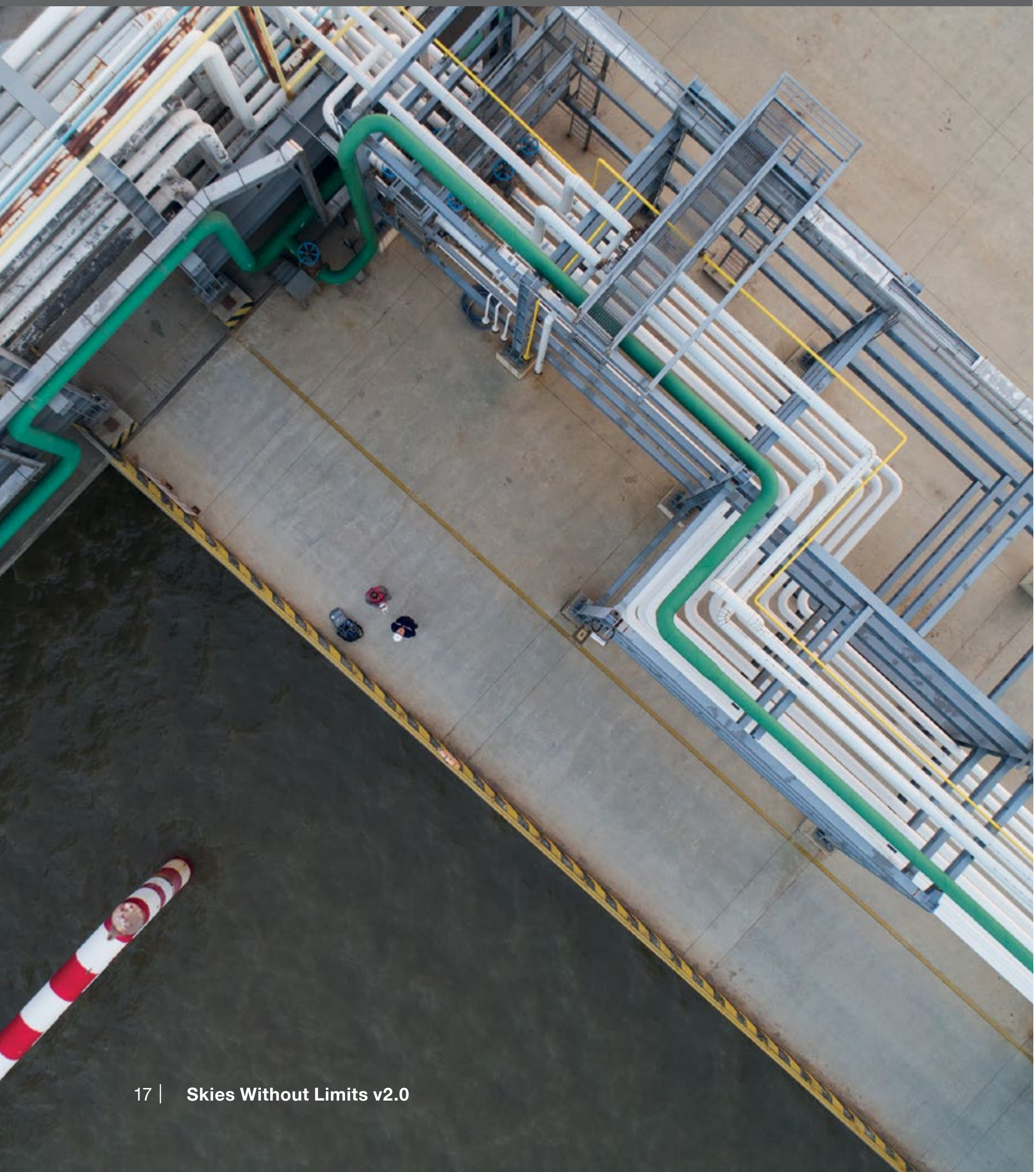
In addition to 270,000 directly affected jobs, we would estimate that a further 380,000 jobs would benefit from drone adoption e.g. from the profits created in the drone economy that are reinvested, inbound flows from overseas investors who are able to benefit from the wider economic effects that drones bring, or from the efficiency effects that drones can create in the whole economy's supply chain.

The combined effects are that around 650,000 full time equivalent workers in the UK economy would benefit from drone adoption.

Drone Numbers

Turning to the number of drones that will be flying in UK airspace, we've estimated the UK's total population of drones that will be in use by commercial organisations and government in 2030. As Table 3 shows, we project that there will be more than 920,000 drones flying over the UK, split across several industries.

4
Sector review and case studies



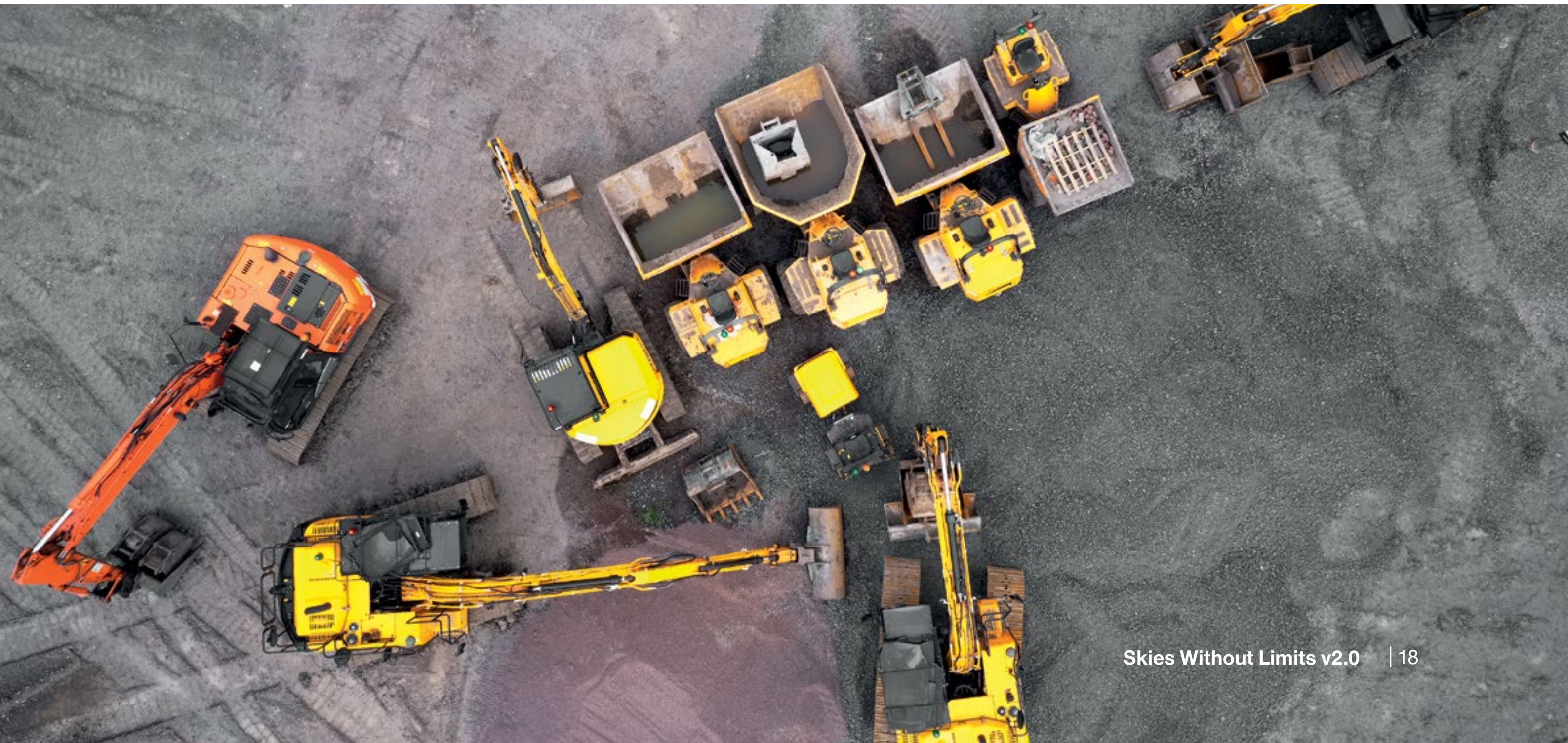
Drones are making a difference right now and these compelling solutions must be scaled up and enhanced to realise the 2030 projections in this report. This section explores the impact of drones in each sector and presents some inspirational case studies which illustrate the potential for drone transformation. The majority of the case studies feature exciting UK startups and forward-thinking entities, evidencing the UK's ability to innovate and drive change in both the private and public sector. Many of the case studies feature innovation and close collaboration with the UK regulator and pave the way for a future where we enjoy the benefits of Routine BLVOS.

> "Case studies feature exciting UK startups and forward-thinking entities, evidencing the UK's ability to innovate and drive change in both the private and public sector.

There are 13 case studies, covering use cases as diverse as **BVLOS** methane detection in the North Sea to delivery of coffee in Ireland. What they have in common is;

- Flying in a "business as usual" mode, with either paying customers or forming a core part of public services
- Delivering tangible benefits (faster, safer, cheaper, better for the environment) right now
- Have only "scratched the surface" and there is considerable potential for growth

In the course of collating these case studies, we asked the entities involved what they considered were the main barriers to growth. The recurring theme was legislation/regulation, particularly the pace at which new rules evolve. Perception, hesitant clients and a lack of specific drone qualifications were also noted.



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Sector review and case studies

Delivery and Survey

Perhaps the biggest change since our 2018 report is in the area of **Last Mile Delivery** where we see significant potential for drones to deliver takeaways, groceries and packages. The main impact of **Last Mile Delivery** surfaces in two sectors, *Wholesale, Retail Trade, Accommodation and Food Services* and *Transport and Logistics*. We estimate that the addressable market in these sectors is of the order of £10bn but note that we are close to zero in 2022 and that many changes including public and **Industry Perception**, the manner of drone implementation, technology, regulation and skills (refer to the "Unlocking Drone Potential" section above) are required to realise the potential of this exciting use case.

This industry sector has the second largest GDP impact (see Table 2, above) and 77% of its cost savings are driven by the Food and Drink sector, which is primarily due to the **Last Mile Delivery** use case. On demand drone delivery of takeaways and groceries could enable a fundamental shift in consumer behaviour with faster, safer, cheaper deliveries that are better for the environment. **Last Mile Delivery** in this sector may also grow the market by realising untapped potential but this has not been modelled in this report.

Last Mile Delivery is similarly impactful in *Transport and Logistics* and we expect *Postal and Courier* to contribute the bulk of the cost savings (67%) in this sector. We also see potential for **Middle Mile Delivery** which, combined with other use cases such as inspection of roads and infrastructure, survey and surveillance enable the *Transport and Logistics* sub-sector to deliver the majority of the GDP impact (also 67%). We note that drones may directly impact other parts of a transport and logistics process, for example drones are at the early stages of being used for inventory management in warehouses.

Finally, we expect drones to continue to drive efficiencies in the *Rail* sub-sector, particularly in the area of **Inspection** and **Survey**, contributing 26% of the sector GDP impact.

Industry sector

	Wholesale, Retail Trade, Accommodation and Food Services	Transport and Logistics
GDP impact	£13.3bn	£2.8bn
Cost Savings by 2030	£3.7bn	£4.2bn

The following case studies cover **Last Mile Delivery, Middle Mile Delivery** and **Survey**.

Food, Parcel and Medical "Last Mile" Delivery – Could We Go a Little Faster?

Last Mile Delivery is concerned with transporting packages to their final destination, for example a parcel or takeaway. **Last Mile Delivery** at scale means large numbers of drones in the sky and this volume of air traffic requires effective solutions for **UTM**, **Electronic Conspicuity, Detect and Avoid** and **Drone Autonomy**, especially in busy city locations. High drone numbers also have the potential to limit societal acceptance, with delivery drones being one of the least popular use cases in PwC's **Trust in Drones Survey**. Only 26% of respondents supported the idea of drone deliveries, however, more recent surveys suggest that approval ratings can drastically increase once a population has experienced the benefits that drone deliveries can bring. **Last Mile Delivery** solutions also face challenges in terms of packing, take-off **Infrastructure** and delivery landing locations. The latter point is perhaps not as challenging as it first appears, with 85% of the UK population living in detached or semi-detached houses.

The **Last Mile Delivery** of food and parcels is a rapidly growing market, with food delivery growing by 48.1% in 2020 (Lumina Intelligence UK Foodservice Delivery Market Report 2021). This is despite the fact that using cars, vans and motorbikes for **Last Mile Delivery** contributes to congestion, causes pollution and can be expensive. Accordingly, the size of the **Last Mile Delivery** opportunity for drones is huge, with an estimated TAM (Total Addressable Market) of £10bn. As a result, there have been attempts to bring last mile drone delivery to life in the UK, but so far nothing has been deployed in volume. Amazon Prime Air recently wrapped up their operations in the UK to focus elsewhere, despite conducting their first drone delivery trial in Cambridge as far back as 2016.

In contrast to the lack of last mile drone deliveries in the UK, there are examples of successful drone delivery services in other countries, some of which are close to home. For example, in Ireland, Manna offers rapid delivery of "coffee, food, medical supplies and more" and currently operates in three locations. A customer can place an order via their app and see it delivered minutes later via drone. The package is lowered to the customer via a biodegradable tether that detaches with the parcel, meaning that the drone does not need to land. Manna's approach is enabling smaller local companies to reach customers with faster delivery times than any other alternative, including the one day delivery times offered by larger corporations. Manna advises that they have completed over 75k flights to 17k+ customers, and consider that drone delivery is close to becoming a normal part of everyday community life.

If we look at the global picture for **Last Mile Delivery** drones, we can conclude that other countries such as Ireland, USA, Iceland and Australia have made more tangible progress than the UK. This does not appear to be due to technology (**UTM**, **Electronic Conspicuity, Detect and Avoid** and **Drone Autonomy**, etc.) which is not notably different. It may be due to a different attitude to risk in the UK and, while we wait for technology to advance, there is an opportunity to progress in the meantime, learning from the **Last Mile Delivery** drone progress around the globe.

Manna says:

"In a world where the operating cost of a road-based delivery is over 6EUR, our partners have enthusiastically embraced a system that provides them a low cost, quiet, private and emissions free solution connecting them to their customers over a total combined operating area of 30 square miles. The local merchants working with Manna can now provide the 45,000 residents (13,000 homes) in our operating area with a better at-home delivery experience than the biggest logistics-focused online retailers on the planet. Better still, as most of our operations have a flight time of just 3 minutes we have seen new customer behaviour around use cases like coffee delivery, and highly perishable products. All local, offline businesses become online with drone delivery. This increases overall demand, and therefore local businesses become more profitable, and jobs are created in the local economy. Already we have delivered to 40% of the homes in our operating area, and have a significant customer cohort of over 50 deliveries each – in only 12 months of operation."

New Logistics Using Existing Infrastructure to Connect Communities

Drone deliveries are often the first thing that come to mind when asked to consider a “futuristic” drone use case. However, due to some of the complexities noted in the **Last Mile Delivery** case study above, it can sometimes be difficult to imagine a sky filled with drones delivering food and parcels directly to homes in built-up, congested areas such as London.

In contrast, using drones to deliver packages from, say, a warehouse or airport to a staging point prior to the consumer (**Middle Mile Delivery**) is less of a leap. These cargo drone deliveries are less complex than deliveries to consumers and have the potential to use existing infrastructure and integrate with existing air traffic. The cargo drones currently used for **Middle Mile Delivery** typically resemble something more like a small traditional fixed wing aircraft and can carry considerably larger payloads than the small drones associated with consumer delivery. By sending more packages via the air, congestion and emissions can be reduced on the roads below and remote communities can be more easily reached.

One company delivering in this area is Windracers. They currently have trials operating across the UK between the mainland and nearby islands. Their drone can make use of existing airport and aerodrome infrastructure, utilising runways to take-off and land, making it easier to quickly implement new operations.

During the COVID-19 pandemic, Windracers used its drone to deliver medical supplies to locations with remote communities in a quick and efficient way. Windracers’ solutions are also better for the environment than manned aviation, with the company claiming a 30%+ reduction in carbon emissions from their initial trials. The drone has a payload capacity of 100kg, a range of up to 1000km and can fly in weather conditions that would ground manned aviation.

Operations like these could make a big difference to island communities that would have often found themselves cut off for large proportions of the year, significantly improving their healthcare and logistics.

It is expected that over the next decade the capacity of **Middle Mile Delivery** drones will increase, which will continue to drive their adoption. In our **Future Flight Challenge** Report model of cargo drones, we noted that drones with a capacity of 350kg could replace existing airfreight and deliver a 34% saving, as well as increasing quality and flexibility on the modelled route. Future applications will feature multiple simultaneous flights controlled from a central operations hub with high levels of autonomy enabling one controller to oversee tens of deliveries. We also expect that, with new battery technology, long range **VTOL** cargo drones will appear, further increasing the flexibility of a solution that already looks compelling with fixed wing drones and runways.

“Drone deliveries are often the first thing that come to mind when asked to consider a “futuristic” drone use case.

Windracers says:

“This year, the Windracers team have proven our 100kg payload ULTRA system platform performance, with scheduled services in some of the toughest operating environments the UK can present to us. In connecting the communities where we have flown services, in the Orkneys, Fair Isle and Isles of Scilly, we have shown what a step change in services we can deliver, in the health care and logistics sectors. We are seeing large environmental benefits too, with significant CO_2 emission reductions when compared to existing transport methods. These environmental benefits will only improve as we move to electrical and hydrogen propulsion systems. We look forward to the next 18 months where we will roll out services at network scale.”

Highly Accurate Drones Keeping Passengers and Engineers Safe and Minimising Commuting Delays

The inspection and survey of railways plays a key role in the safety of the millions of people who use the UK rail network every day. There are high standards to adhere to in everything from inspections to measuring how close trees are to the track. The challenge is how to carry out these tasks effectively without causing disruption and delays to the overall service.

Drones are certainly one of the answers, meeting many of the requirements of "traditional" **Inspection** and **Survey** methods but, unlike many traditional approaches, without a need to stop trains running or walk the track. Drone operations are also safer, faster and require fewer people, dramatically reducing the hours of staff exposure to risk.

Drone surveys can deliver precise models and Plowman Craven are an example of a company that has achieved a very high degree of accuracy for rail applications. Their solution delivers +/ – 5mm absolute accuracy and meets Network Rail's "Band 1" accuracy requirement. This allows Plowman Craven to carry out track alignment assessments with their drone (the Vogel R3D), all whilst staying 25m above the track, out of the way of the trains and without compromising accuracy.

Network Rail has been an early adopter of drone technology and has a well-staffed pilot roster, several relationships with drone service providers and an end-to-end drone workflow. Moving forward, Network Rail is keen to increase the efficiency of drone solutions by using **Routine BVLOS** drone flights to, for example, measure vegetation encroachment. They have already begun conducting **BVLOS** trials, completing a 25km drone flight over tracks in Oxfordshire at the end of October 2021.

"There are high standards to adhere to in everything from inspections to measuring how close trees are to the track.

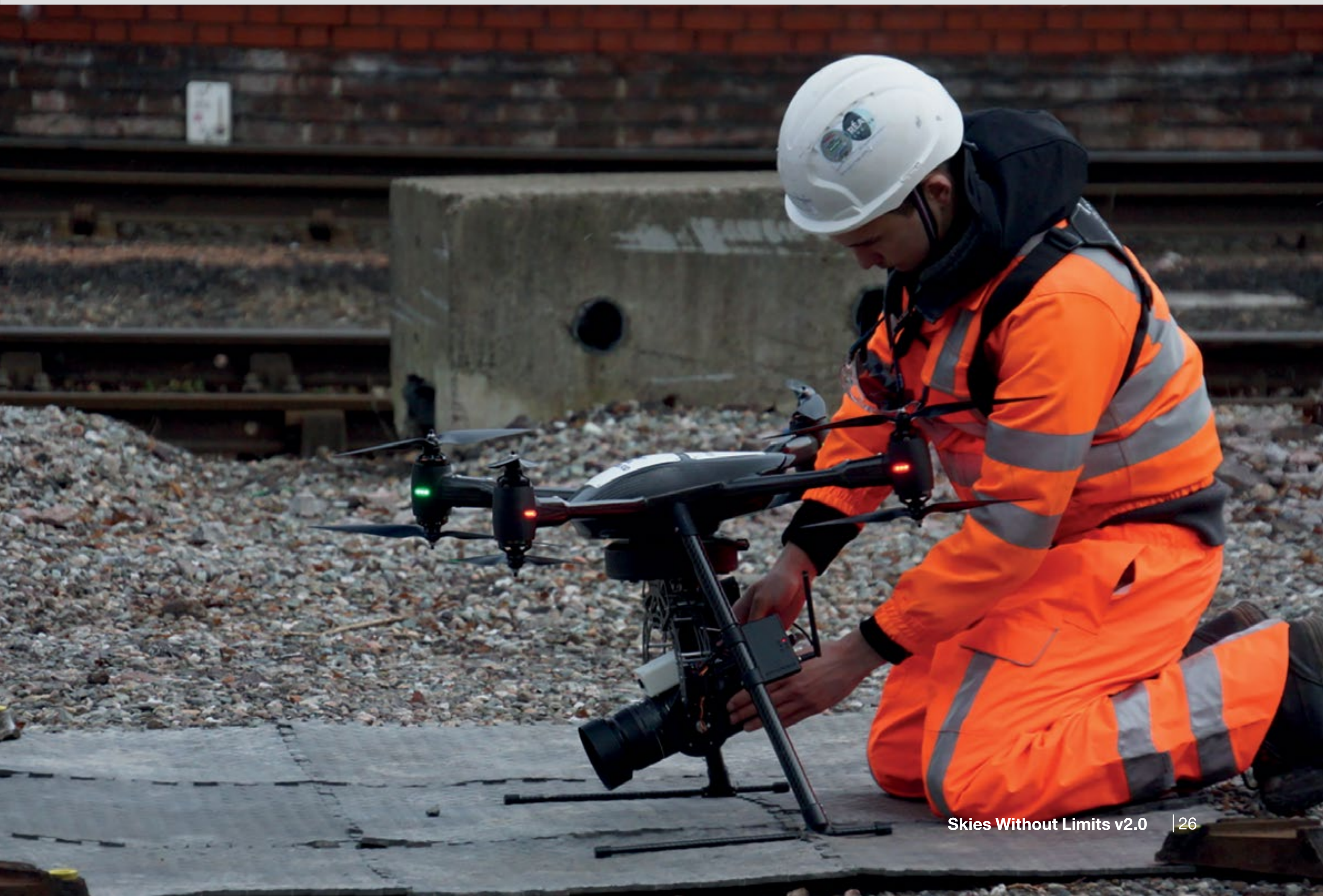
Plowman Craven says:

"Safety is of paramount importance and is driven by Network Rail's own "boots-off-ballast" approach. The Vogel R3D system virtually eliminates track access, but in doing so also provides a significant reduction in programme time. A typical 6-week lead time for track possession can be avoided, leading to faster project deployment and completion, with the associated reduction in risk and cost.

Where the Vogel R3D differentiates itself is the degree of accuracy obtained from the system. The robust survey workflows and latest technology combine to provide what is claimed to be one of the world's most accurate UAV Survey Systems. In fact, the system is being developed further to enable visual inspection of switches and crossings. Tolerances for this type of work go far beyond Band 1 accuracy, with some activity requiring +/ – 1mm accuracy.

Solving problems such as this opens up further opportunities with machine learning. The ultra-high resolution images provide the perfect starting point for software algorithms to do the hard work of identifying features, issues, missing P-Way, cracks and wear. Track engineers can then focus their skills on identified areas of concern rather than walking miles of track in the dark.

One of Network Rail's Senior Engineers states: "The application of the Vogel R3D system is a real game-changer for Network Rail and helps us to satisfy many of our survey requirements in a safe manner without the cost implications or potential programme delays associated with multiple possessions.""



Data

Before we delve into the other sectors and case studies, we will cover a key topic that is relevant to all sectors – data. As discussed in the “Unlocking Drone Potential” section above, whether a drone solution delivers the expected benefits will often boil down to how effectively data is captured, processed and integrated with business as usual.

The Criticality of Integrating Drones with Business-as-Usual

Most organisations understand that the value of drone solutions is in the data. However, this understanding is not always reflected in drone implementations and, as a result, not all the anticipated benefits materialise.

Organisations who choose to implement drones do so with the expectation that they will be faster, cheaper and safer than existing approaches. The physical nature of the technology can often lead to a perception that drone implementation is complete when drones are purchased and pilots trained or a drone service provider is chosen.

This is only part of the story and common drone implementation pitfalls include:

- More focus on “flying or buying drones” than on how to generate fit-for-purpose data that is integrated with existing systems
- Drone data not shared effectively with all stakeholders
- “Siloed” drone use in different areas of the company or project, resulting in data of varying standards and often in the duplication of data capture
- A lack of centralised governance and control over the organisation’s drone use
- An immature procurement process for drone services risking higher costs and data that is not fit-for-purpose

These issues emerge when a company does not consider the entirety of the drone workflow (see the next page), before starting the implementation.

> “Organisations who choose to implement drones do so with the expectation that they will be faster, cheaper and safer than existing approaches.

PwC's 4 step drone workflow model

1 Permission	2 Capture	3 Processing	4 Sharing
• All required authorisations are place for the mission. • Considerations include VLOS, EVLOS, BLVOS and congested area operations. • Pilot capability and currency, system selection and maintenance validation.	• Flight planning, Risk Assessment and Method Statement (RAMS), mobilisation. • Drone is flown in accordance with the plan and applicable regulations. • Data (image, lidar, etc) is captured and uploaded.	• Conversion from data to actionable information. • Usually commoditised photogrammetry software for survey deliverables. • Inspection deliverable processing may include computer vision AI, usally significant manual intervention from engineering.	• Processed information is shared with the client. • Ranges from PDF documents to interactive cloud-based **Visual Asset Management** (VAM) solutions. • Client systems intergration is key, both existing processes and systems such as BIM and ERP.
Fleet management sw		Processing sw	VAM sw

VLOS – Visual Line of Sight; **EVLOS** – Extended Visual Line of Sight; **BVLOS** – Beyond Visual Line of Sight; **BIM** – Building Information Modelling; **ERP** – Enterprise Resource Planning; **sw** – software

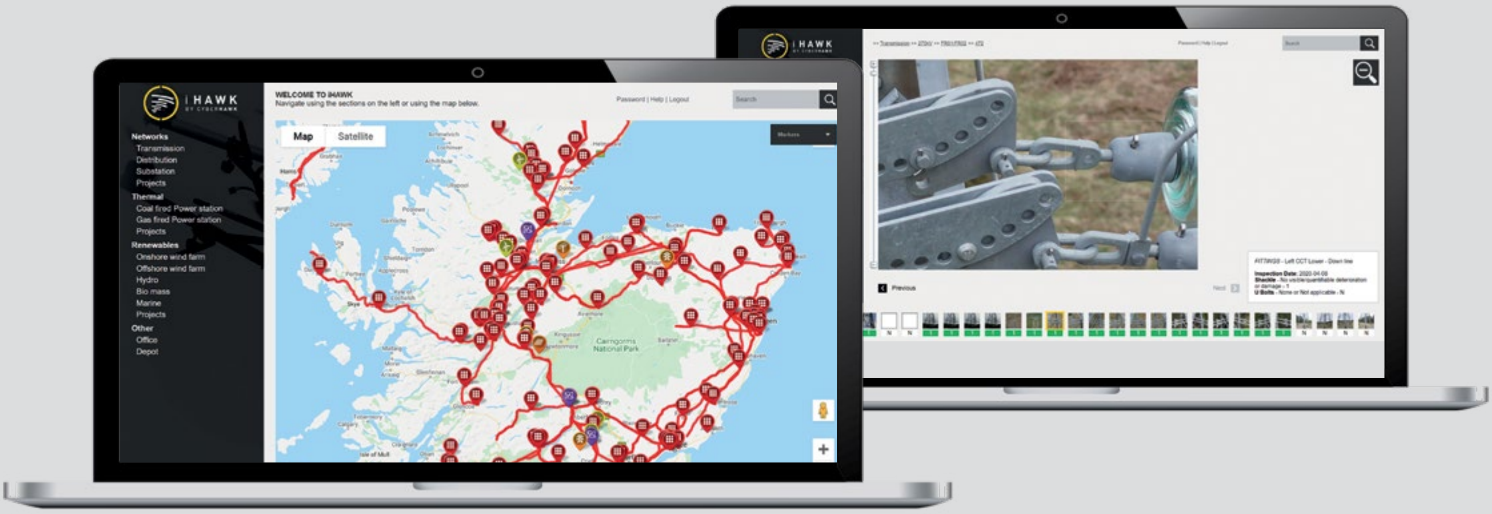
One way to ensure that all aspects of the workflow are considered is to "start at the end", making sure that there is a clear understanding of exactly how drone captured data will ultimately be used, who will use it and which existing systems it must integrate with. It is also key that all relevant stakeholders are involved in this discussion, and that equal weight is placed on all four steps of the drone workflow. This approach ensures that the drone implementation is driven by a clear need and meets the precise end user requirements. The most effective implementations also include Fleet Management software and Visual Asset Management (VAM) software.

One company with a history of transforming how its clients "Share" data (step 4) is UK-based Cyberhawk. Cyberhawk has built a VAM software solution called "iHawk" that enables their client's stakeholders to intuitively view drone-captured and other relevant data in the cloud, using a simple map-based interface, with just a browser required to access. The VAM data is often integrated with their client's existing systems.

Cyberhawk says:

"Cyberhawk helps SSEN Transmission monitor over 11,500 transmission towers and almost 150 substations, providing actionable insights via its cloud-based, GIS and IoT-enabled visualisation platform, iHawk. The adoption of iHawk has offered SSEN Transmission's operational, project and asset teams unprecedented levels of access to multi-level data, allowing them to gain a more comprehensive understanding of the network, exposing integrity and compliance risks, and revealing opportunities for improvement. In SSE's words, "iHawk's innovative approach to data management is key to managing our network assets, central to how our operations team manage inspections, maintenance, safety, and compliance.""

There are already software packages on the market that cover all four steps in the workflow. We expect that this integrated approach will continue to gain traction as organisations realise the limitations of their existing systems when it comes to getting the most out of drone data and achieving efficiencies in their drone operations. We also expect more organisations to focus on demonstrating their compliance with the CAA requirements by adopting organisation-wide Fleet Management software. Fleet Management software enables organisations to oversee all their drone activities from a central dashboard including scheduled and historical flights, pilot currency, equipment condition and in some cases much more. Dronecloud is an example of one UK company providing such software.

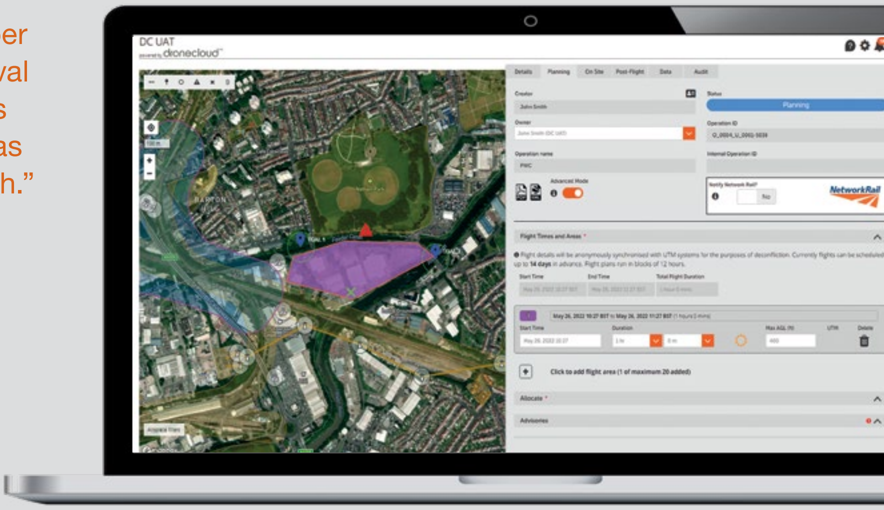


Dronecloud says:

“The Dronecloud platform helps bridge the gap between drone flight management tools (fleet management, logging) and **UTM** systems and services to provide users with the ability to deploy large scale operations safely. Since using the Dronecloud platform, our customers have grown from single-use, low-volume operations to more complex (**BVLOS**) advanced operations, deployed at scale.

Like many of our customers, Network Rail wanted to scale operations but were held back by manual processes. Dronecloud removed Network Rail’s manual workflow through centralised and automated management operations of Flight Approvals, Flight Planning, Airspace, Compliance and Fleet Management. Since using Dronecloud to manage the entire drone operation for 18 months, Network Rail has seen an increase in flights carried by internal pilots of 500% (over 3000 flights per year). In addition, the average flight approval time – which previously took 14 days – has been shortened to under one hour. This has massively increased operational bandwidth.”

Ultimately, with all of the required technology in place (see Section 2, above), we could find ourselves in Industry 4.0. This could mean that flights are triggered by an AI generated requirement, such as a planned maintenance schedule or an alert, and all four steps of the drone workflow model are carried out automatically, including **Autonomous** drone flight. In this scenario, human involvement would only be required if anomalies are detected by the **AI** analysis of processed data. There is even the chance that this **AI** analysis could happen in “real time” on the edge, i.e. at the drone itself.



Sector review and case studies

Emergency Response and Building Inspection

The industry sector with the highest potential GDP impact and cost savings is Public and Defence, Health and Education. There are a number of ways that drones of all shapes and sizes can be used in the public sector. Emergency services is an obvious group who can utilise drones to gain additional insight from their air; for search and rescue, crime monitoring and flood/fire impact assessments. We pick up two of these use cases in the Environment Agency (flood) and Maritime and Coastguard Agency (search and rescue) case studies in this section.

There is also a significant amount of infrastructure in this sector, much of which can be more effectively inspected using drones than traditional approaches. In addition to being faster, safer and cheaper, drones can often deliver more comprehensive asset coverage. This is illustrated in the Renfrewshire Council case study captured by the Connected Places Catapult (CPC).

Industry sector

Public and Defence, Health, and Education

GDP impact	Cost Savings by 2030
£14.1bn	£4.6bn

Teaming Manned and Unmanned to Deliver Effective Search and Rescue in UK Waters

According to PwC's 2019 Trust in Drones Survey, drone use for emergency services is one of the most popular use cases among the public. Respondents supported the use of drone technology to protect people from harm, with 87% of respondents approving of drones for search and rescue. Drones are a tool that have been widely adopted by the emergency services in the last few years, with a range of use cases that are saving lives. Between 2017 and February 2022, DJI recorded 68 instances of drones saving lives in England and Wales alone.

Search and rescue (SAR) is one of the most obvious lifesaving use cases for drones. The birds-eye view that they offer enables rescuers to gain a new perspective on their surroundings and allows them to access hard to reach areas with ease.

Through use of a thermal imagery sensor, drones can quickly identify the body heat of missing individuals, which is especially useful during operations with poor conditions and low visibility. The rapid mobilisation speed of drones is also critical when every second counts. With their ability to complement traditional approaches and give professional rescue teams new tools to assist their search, it is clear why they have been so readily adopted by a range of UK emergency services.

The Maritime and Coastguard Agency (MCA) must respond to SAR incidents anywhere within the UK Search and Rescue Region (UKSRR), which is approximately two million square miles. In 2016 they began looking into the advantages that **BVLOS** and **VLOS** drones could bring to both their counter-pollution and search and rescue operations, when used in combination with existing helicopter operations. **Routine BVLOS** flight is key for drones to meet the MCA's requirements and their work with the **CAA** has already delivered a successful demonstration of safe integration with **Unsegregated Airspace** (see next page).

Once **Routine BVLOS** drone flights in **Unsegregated Airspace** are possible, the future is likely to see further advances in the use of drone technology for SAR. Multiple drones could work together as part of a swarm to rapidly and efficiently search vast areas of land and sea, bringing further improvements to rescue times. Drones may also play a more active role in the rescue itself, with abilities to deliver life-saving equipment directly to those in danger, and larger drones potentially air-lifting injured individuals to safety.

The MCA says:

"To assist with the development of the regulation and airspace, the MCA has, and continues, to work closely with the CAA and has run several demonstrations and trials, utilising large persistent drones and smaller drones, to ascertain the potential value for operations as well as to assist in the development of the regulation.

The MCA recognises the potential advantages that drones could bring to SAR response in the UK, increasing the effectiveness and efficiency of the search whilst reducing the risk to MCA personnel and the overall rescue community.

Potential drone usage ranges from persistent support of enduring SAR operations, to support of rescue teams engaged in coastal rescues and all points in-between throughout the UK Search and Rescue Region (UKSRR). Preventative measures such as beach patrols to pinpoint danger areas and proactive counter pollution operations could also potentially be performed by drones. To achieve this, routine, regular operation of **BVLOS** drones without the need for special permissions or segregation of airspace is critical.

Manned unmanned teaming is critical to SAR operations and the MCA has been working with its current SAR helicopter provider, Bristow Helicopters Limited, to trial the use of a rotary wing drone in conjunction with the SAR helicopters. The MCA took advantage of this capability during summer 2021 to perform proactive beach patrols of North Wales."

Faster, Safer and Cheaper Building Inspection

Keeping our houses in good structural condition is a priority for many of us. Major repairs can be costly and disruptive and, of course, best avoided. For housing associations that manage large portfolios of property the scale of the potential issue is much greater and it can be challenging to stay on top of every repair issue, often leading to repairs that are more expensive than would be the case if issues were detected earlier. The CPC states that in social housing alone, more than £6.3bn is spent annually on repairs and maintenance in the UK.

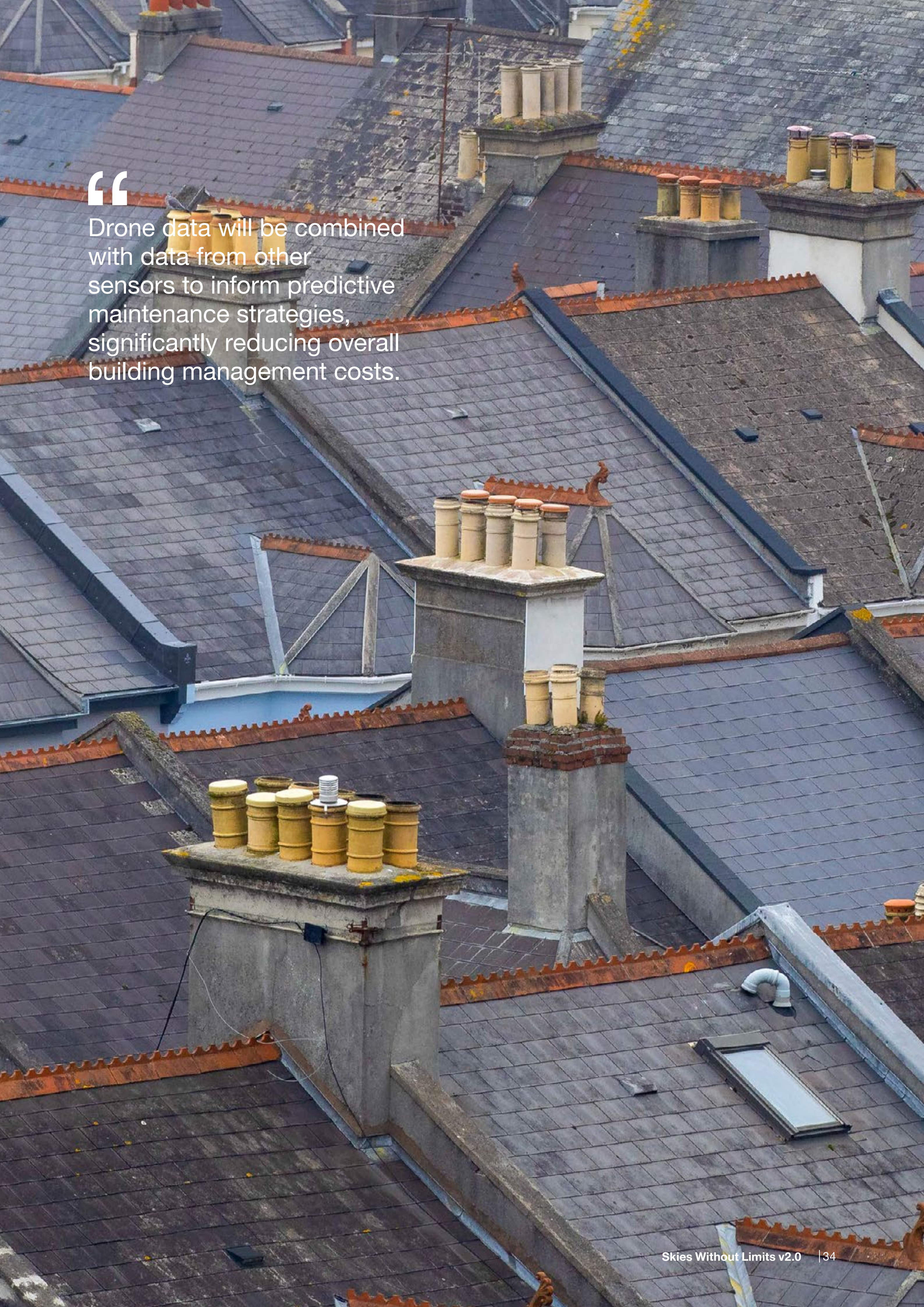
Drones have considerable potential when it comes to building inspection. They can deliver a cost-effective, comprehensive perspective of building exteriors, without the need for scaffolding or working at height. They enable faster, more frequent inspections and, often, earlier detection of issues. Disruption for residents is minimised. Insulation actions can also be targeted by using drones equipped with thermal imaging cameras.

Renfrewshire Council has embraced drones and plans to use them to inspect the 12,000 properties in their social housing portfolio, potentially generating a saving of £4M per year. There are a mix of property types in the portfolio, including 14 high rise towers, all of which need ongoing façade and roof inspections.

Prior to 2016, the council relied on scaffolding and mobile elevated working platforms (MEWP) to carry out this work, which was slow, costly and exposed staff to working at height. Implementing drones has enabled them to carry out entire programs of inspection in under two months, a process that used to take years. The data that the drones gather is therefore enabling smarter, more informed decision making and enabling them to move towards a predictive maintenance approach.

The future will see operations like these on a larger scale, with increased levels of drone autonomy and, perhaps, edge **AI** analysis of defects. Drone data will be combined with data from other sensors to inform predictive maintenance strategies, significantly reducing overall building management costs. There may also be **Autonomous** drones that are able to act on the data gathered, taking steps to fix simple issues such as missing or cracked roof tiles. Drones are also being used for preventative measures such as spraying buildings for cleaning or vegetation treatment and we expect this to become commonplace, perhaps automatically triggered by the findings of an autonomous inspection drone.

"Renfrewshire Council has embraced drones and plans to use them to inspect the 12,000 properties in their social housing portfolio, potentially generating a saving of £4M per year.



“Drone data will be combined with data from other sensors to inform predictive maintenance strategies, significantly reducing overall building management costs.

Rapid Response at Times of Environmental Crisis

The UK has seen a number of major flooding events in recent years, with both changes in climate and the built environment having a large impact on the floods that we see. February 2020 was the wettest on record in England and the Intergovernmental Panel on Climate Change says 'once-a-century' sea level events will occur annually by 2050. The economic losses from the winter 2019/20 flooding are estimated to be about £333 million, however flood prevention measures are thought to have avoided economic damage of at least 14 times this amount (refer to National Flood and Coastal Erosion Risk Management Strategy for England). Despite new flood defences, flooding cannot be stopped completely, and it is therefore important that it is dealt with effectively when it occurs.

Drone technology can assist here, providing a number of benefits in the immediate aftermath of a flood. It is vital that action is taken quickly, to enable informed decision making, minimise disruptions and, in more severe cases, save lives. The unique aerial perspective that drones offer is particularly useful. Through streamed video and photogrammetric processing of images, drones can quickly and easily highlight the extent and magnitude of flooding using the data that they collect. This information can be utilised by a number of stakeholders, from first responders on the ground to insurance companies.

Depending on the sensor that is attached to the drone, they can also be used for a variety of other purposes. Search and rescue teams can utilise drones with thermal imagery cameras to identify individuals who may be stuck inside their homes or other hard to reach places. Communications providers can also put drones in the air to act as temporary cell towers, removing network downtime whilst key infrastructure is brought back online and allowing those in the area to coordinate response efforts.

The Environment Agency (EA) is very aware of the need to act quickly in the aftermath of a flood. They have a 24/7, 365 days per year drone response service, which aims to mobilise and stream a live video feed within six hours of an incident. In the past, these live images have been used in incident control rooms and meetings to assess the impact of flooding and give insight to key decision makers. Drones play a critical role in the coordination of a more efficient response to flooding, illustrating their significant value in a non-commercial environment. The EA currently outsources these drone operations to RUAS, who has a large fleet of drones which can be operated simultaneously from three different geographical locations during and after environmental incidents.

Drone data can also be used to shape flood defences and as a key input into the planning and modelling of various scenarios. In the future, we anticipate that drones will function as an integrated part of a real-time flood modelling and response solution, combining **AI**, predictive models, **IoT** sensors and big data to optimise flood responses. The drone data could be captured by autonomous **Drone-in-a-box** solutions which are strategically placed around the UK and able to fly **Routine BVLOS** with little or no pilot involvement. Flights from these drones would be triggered routinely or in response to the predictive flood model (incorporating big data) and/ or **IoT** sensor alerts. Such a solution should be better for the environment, be able to respond more quickly, improve communications and ultimately reduce the cost and environmental impact of floods.

> "24/7, 365 days per year drone response service, which aims to mobilise and stream a live video feed within six hours of an incident.

The Environment Agency says:

"Presenting to senior emergency management staff our live drone footage of the temporary barriers at Ironbridge helped to sustain our credibility as a competent operator of choice and bolster their own confidence through observing what was actually happening rather than listening to what others thought was happening."

Sector review and case studies

Infrastructure Inspection

Today, most of the benefit that drones bring to the TMT sector comes from inspection of infrastructure. Improvements to safety and efficiency can be gained through the use of drones to inspect assets that are often at height. However, unlike some other sectors, there are also a number of more innovative drone use cases that are beginning to emerge for drones in this industry such as; line of sight testing/signal testing, temporary network signal creation (see "Rapid response at times of environmental crisis" case study above) and wire carriage when implementing new infrastructure. Many of the use cases written about in this report that will emerge over the next decade will also depend on strong telecommunications networks with high bandwidth and low latency (see the "Unlocking Drone Potential" section, above).

The **Remote Piloting** use case below uses a range of communications systems to enable safe flight operations over long distances and in remote locations.

Industry sector

Technology, Media and Telecommunications

GDP impact	Cost Savings by 2030
£2.4bn	£0.9bn

Remote Piloting Paving the Way for Autonomous BVLOS

For the most part, in the UK drones must be flown **VLOS** (typically no more than 500 metres from the pilot). **BVLOS** flights are generally not allowed except in a **Segregated Airspac**e corridor where no other traffic is permitted to fly and then only after case-by-case authorisation from the **CAA**. However, **BVLOS** flights have the potential to bring a number of benefits to UK drone operations. In our **Future Flight Challenge** Report, we compared **VLOS** drone powerline inspection with its **BVLOS** equivalent and noted a 35% cost saving, along with significant efficiency, staff safety and quality benefits.

This scenario featured an Edinburgh based pilot over-seeing the flight of a **VTOL** (vertical take off and landing) drone which inspected powerlines that were many miles away in central Scotland. There are several challenges to overcome to realise these benefits, from drone and battery technology to holding "business as usual" permission to fly **Routine BVLOS** in **Unsegregated Airspace**.

sees.ai is one of the first UK drone operators to be granted permission to fly **Routine BVLOS** flights in **Unsegregated Airspac**e (at specified locations) without pre-authorisation for each flight. Their remote pilot is able to design and oversee routine drone operations at a separate location from where the data is captured. sees.ai's clients include electrical utilities, oil and gas sites and large infrastructure projects. Their remotely-piloted **BVLOS** drones can capture inspection data at close quarters at a comparable quality to **VLOS**, but with the added benefits of standardisation and the ability to scale up operations more simply and cost-effectively.

These sees.ai permissions pave the way for an exciting growth in **BVLOS** drone operations over the coming decade. We expect a combination of drones flying from a central location to their point of use and drones housed near the point of use being operated remotely. Indeed, future **BVLOS** drone operations may not even require a pilot, with missions simply launched by those that require them to meet inspection schedules or respond to alerts, for example. Although we can already see global examples of this operating model, technology and legislative developments will be required for them to become business-as-usual in the UK.

sees.ai says:

“After several years of experimentation with drones, our industrial partners and clients understand that remote operation and autonomy is key, so we are working with them and the Regulator towards making **BVLOS** operations routine in industrial contexts.

We leverage advanced onboard autonomy and real-time 3D mapping to present a solution that is more capable both from a performance and permissions point of view. This means we are able to address a wider range of missions, capture better data; and present it in a better way.

Cost savings for monitoring and inspection range from 30-60% depending on the nature of the operation and factors such as the degree of hazard and access involved. But saving money on inspections is rarely the primary objective – instead the aim is to improve inspections in order to reduce expenditure on maintenance and increase the performance of the world’s most valuable assets. The system is safer and greener than conventional methods of monitoring and inspection, which also enhances its appeal.”

Energy, Utilities and Agriculture

The use cases in this sector are often well established, with inspection and survey of assets already regularly taking place across many sub-sectors such as utilities, oil and gas and mining. Many of the cost savings and GDP impact seen over the next decade, therefore come through efficiencies in these use cases, rather than completely new ways to use drones. We feature an oil and gas case study below which uses **BVLOS** drones to monitor emissions. From the utilities sector, we have a case study from the water industry where drones are being used to detect leaks, in addition to the more common infrastructure use cases.

In contrast to the more established sub-sectors listed above, sub-sectors such as Agriculture and Forestry are far from reaching their potential in the UK. The Agriculture sub-sector is potentially significant and we estimate that it could account for more than 50% of the potential GDP impact in this sector. Opportunities for drones exist throughout the agricultural lifecycle from monitoring crop health, to seeding and spraying crops and we cover this in the precision agriculture case study below.

Industry sector

Agriculture, Mining, Water, Gas and Electricity

GDP impact	Cost Savings by 2030
£3.0bn	£4.4bn

Deploying BVLOS Solutions in a Mature Drone Market

The Oil and Gas industry was one of the earliest adopters of drone technology due to the clear benefits it could bring. For instance, the use of drones to inspect live flare stacks could save an offshore platform £4 million per day (refer to **SWL1**) as there is no need for the shutdown that would be required for rope access. Drone use is now widespread, with other common applications including internal storage tank inspections and real time methane detection. This has brought with it large cost savings as well as vast improvements in health and safety, with a reduced need for employees to work in hazardous environments.

The industry's relative maturity has not slowed the adoption of more advanced drone technologies. In recent years, some companies have begun to use fixed wing drones for **BVLOS** (beyond visual line of sight) flights over offshore oil platforms. The approach enables the pilot for these flights to remain onshore and monitor the drone's flight and data collection. This has started to deliver further efficiencies to an industry that was already thought to be close to realising the maximum potential of **VLOS** drone use.

One company pioneering **BVLOS** in Oil and Gas is Flylogix. They fly **BVLOS** drones to monitor methane emissions from offshore platforms, amongst other activities. In 2017 they successfully conducted their first **BVLOS** drone flight over the Irish sea, gathering data from an oil and gas platform 30 miles from the onshore pilot. They now conduct **Routine BVLOS** methane detection and facility monitoring flights over most of the North Sea oil platforms and have already made inroads into other new markets and territories. Their success demonstrates the potential that can be realised by understanding the market, building the right technology and working collaboratively with the **CAA**.

Flylogix says:

"Unmanned aviation has the potential to radically change how we operate in remote environments. By removing people from high-risk areas and operations it increases safety and efficiency. It can reduce carbon emissions by up to 100 times (compared to manned vehicles) and is much more cost-effective overall than the methods used to date for things such as offshore monitoring and maintenance. Our drones enable new ways of working that were previously unachievable or not economically viable, not just in oil and gas, but in a number of industries. We have carried out trials and live projects in delivery logistics, emergency response, routine surveillance, methane emissions monitoring.

We envisage our technology providing huge benefits in terms of efficiency, cost-effectiveness, safety and reduced emissions in other areas such as tracking livestock, surveying pipelines, monitoring waterways, for example. We are bringing together artificial intelligence, satellite communication and low-cost electronics to pioneer a new generation of small, highly efficient unmanned aircraft with an operating range of up to 500 kilometres. Every operation is piloted from the shore and monitored centrally, with real-time data and insight."

In the future, in addition to **Routine BVLOS** drone flights, the Oil and Gas industry will likely see an increased integration between drones and other robotics. Use of **AI** to automate processes for data collection, analysis and, in some cases, repair is also likely. Furthermore, we expect increased prevalence of sensors that "touch", building on the current small volume of drones that, for example, can apply probes to surfaces to obtain thickness readings. Oil and gas facilities will increasingly be designed with drones and robotics in mind and these technologies will become an integrated part of the platform. This will lead to a future state where drones will pop out of their integrated "box" on the platform and autonomously fly the missions set by the **AI** core or triggered by **IoT** sensor alerts. The drone feed will be analysed by **AI** in real-time and any repair actions triggered or queued for review.

Reducing Leaks With Smart Solutions

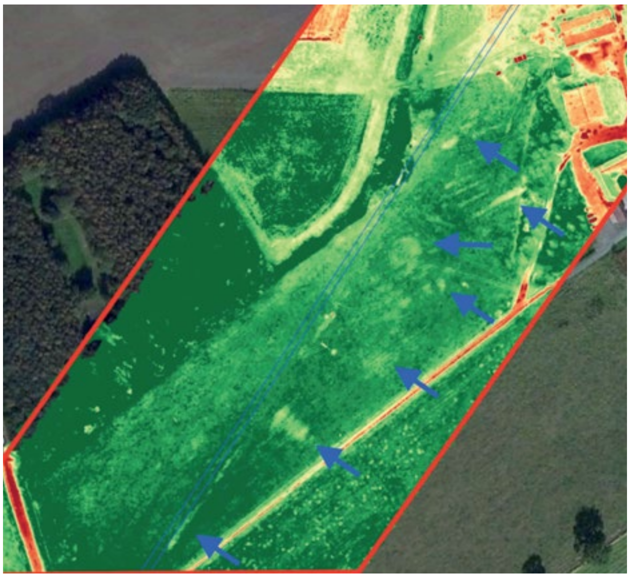
Leaks are a big deal in the water industry. In the UK, it is estimated that just under three billion litres of water per day are lost to leaks. OFWAT has responded to this and set performance commitments for water companies, expecting them to reduce overall leakage by 16% by 2025. Technologies such as drones will play a key part in this due to their potential to detect leaks more quickly and safely than traditional approaches.

Drones can be integrated into a water company's business as usual activities, delivering benefits to multiple operational areas. With a thermal imagery and/or multispectral sensor attached, drones can detect leaks and pinpoint their location, highlighting specific areas for ground crew to investigate and address. They do this by looking for variations in either the temperature or spectral profile of the ground surrounding water pipes and flagging areas that are not as expected. This minimises time spent searching for leaks and may reduce the amount of excavation required for a given issue. Drone use in the water industry is not limited to leak detection, other applications include topographic mapping, asset inspection and "as built" 3D modelling of infrastructure.

> "Drones can be integrated into a water company's business as usual activities, delivering benefits to multiple operational areas.

One drone operator providing a range of services to the Water Industry is Team UAV. Team UAV has combined multispectral cameras with a bespoke algorithm to indicate where leaks may be present, sharing this with their utility client to enable them to target further investigation. They have also used drones to create 3D "as built" models of pump station networks for large UK water companies.

Going forwards, drones are likely to see increased use within the water industry and form a critical part of an overall network of robots and **IoT** sensors. **Drone-in-a-Box** solutions could immediately dispatch drones to locations flagged by **IoT** sensor alerts, enabling rapid, multi-sensor analysis of a problem area. Drones could also be scheduled to periodically capture data which feeds into an overall model of the utility's water network. This could include the use of **BVLOS** drones to autonomously capture water samples that enable ongoing environmental monitoring. The large amount of pooled data continually collected by this network will begin to pave the way for greater efficiencies and predictive maintenance across the water industry.



Team UAV says:

"Drones have not only provided a new and innovative approach to leak detection, but they have increased safety of personnel compared to more traditional methods such as walking the route whilst searching for leaks. They have created efficient workflows, contributed to reducing carbon emissions and lowered the cost of routine inspections. As a by-product of collecting leakage data, we're also able to supply up-to-date asset maps which can be used to plan construction of new pipes or schedule and estimate maintenance of the existing network. Our leak detection method using drones has a 75% accuracy rate and increases efficiency by a factor of ten. As the industry grows and as **BVLOS** regulation develops, this efficiency will grow further."

Automating Traditional Agricultural Practices

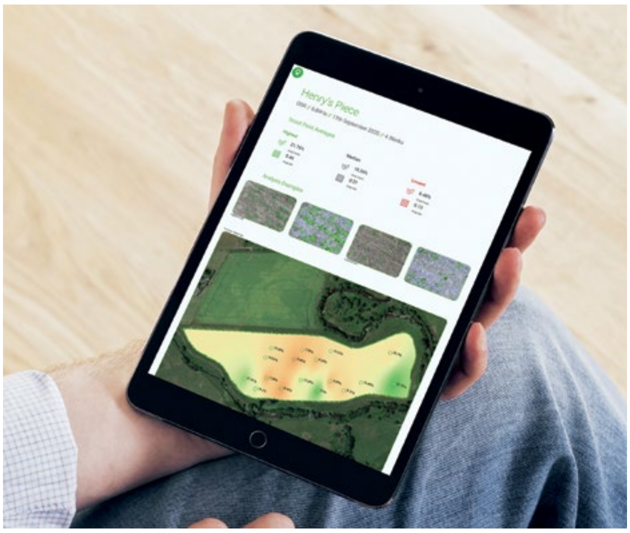
The agriculture industry has a long history in the UK and has experienced multiple technology revolutions. Drones and autonomous vehicles are the latest catalyst for transformation in agriculture and can be used to gather crop health data, spray crops and even seed fields. They are faster, reduce waste, make better use of land, are better for the environment and, ultimately, improve overall crop yield.

In the UK, drones are being used to survey farmland and assess the health of crops. One way to do this is using multispectral analysis such as NDVI (Normalised Difference Vegetation Index), which can differentiate between sick and healthy plants based on how much light they reflect. Other approaches include thermal imagery and analysis of photos. Drones can safely and rapidly give farmers an understanding of the health of their crops, enabling them to target treatments and improve overall decision making.

Drone AG is a company aiming to simplify this process for UK farmers. They use photos and AI analysis to assess crop health and have an app called "Skippy" that enables farmers to fly drones and capture data about their crops through a simple smartphone-based interface.

The app produces a report which identifies how "healthy" a farmer's crops are, whether there are unwanted invasive species growing amongst them and whether this is causing any crop damage.

Detailed crop data like this enables farmers to precisely identify and directly address problems. One action may be to carry out targeted crop spraying using drones. Pioneered in Japan in the early 1990s, there are now several global examples of drones being used for crop spraying. In some instances, using a drone to assist with crop spraying has reduced the amount of chemical sprayed on crops by over 30%.



Drone Ag says:

"We created Skippy Scout with the goal of making the jobs of farmers easier. This translated into saving time and money for the farmer initially, but has other important benefits as well. The Skippy app is highly accessible and controls a standard, off-the-shelf drone, with no special sensor attached, autonomously flying it in order to inspect crops at leaf-level. It automatically works out the fastest route around a field and takes sample photos throughout. These photos are automatically stored, uploaded and analysed using custom AI. PDF field health reports are automatically produced and emailed to the user within minutes of a completed flight, providing the farmer with important and actionable metrics on the crop's uniformity and health.

The current flight algorithm makes this process around 10 times faster than walking. The next algorithm will be 20 times faster. Our own calculations estimate that Skippy Scout saved approximately 100 UK users over 785 hours of labour last season by reducing hours spent inspecting crops on foot. It is also now operating globally across over 18 countries and in over 500 farms. Skippy not only highlights the health of the crop on average, across the whole field, but gives location specific metrics as well. This allows for "variable rate" application of chemicals and fertiliser, as opposed to set rates for the whole field, meaning that the farmer can save money on expensive fertiliser and pesticide. This also means reduced chemical and fertiliser usage, causing less runoff into the surrounding environment."

Despite the benefits, in the UK, the use of spraying drones is currently not permitted under the Chemicals Regulation Directorate (CRD). However, there is mounting pressure for these regulations to be changed, with the May 2021 TIGRR (Taskforce on Innovation, Growth and Regulatory Reform) report encouraging the Health and Safety Executive to "reconsider these requirements at pace" to allow increased innovation within the agricultural sector.

One company looking to capitalise on any potential change is Auto Spray Systems, who has a robot and drone system that work in tandem in an effort to bring efficient crop spraying to the agriculture sector. These vehicles are intended to improve process efficiencies throughout a crop's lifecycle, all whilst lowering associated carbon emissions. After initially mapping crop health in a field, their drone and robot can then get to work on delivering fertilisers to where they are needed most. The intention is that this approach reduces the amount of chemicals used and, accordingly, the impact on the environment. The small size of the robot and aerial nature of the drone also protect the soil from unnecessary compaction.

The ultimate vision for drone use in agriculture is for systems, such as the ones seen in this case study, to "scan, seed and feed". That is, utilise drones at every stage of a crop lifecycle to bring automation and efficiencies. The future of drones in this sector is very dependent on legal changes, which if allowed, have the potential to unlock a more efficient, greener approach to agriculture in the UK.

> The future of drones in this sector is very dependent on legal changes, which if allowed, have the potential to unlock a more efficient, greener approach to agriculture in the UK.

Auto Spray Systems says:

"The optimisation of the rate of application of nitrogen to growing crops is key for both the profitability of agriculture and the wellbeing of the environment. It is necessary to gather information at a very high spatial resolution with regard to the status of both the available soil nutrient content and the development of growing crops in order to make optimal calculations of crop nutrient requirement.

Drones and lightweight autonomous vehicles offer the ideal platforms for a range of innovative sensors which can measure both soil and crop status with ever greater accuracy.

Crop health data is taken from two sources: first a drone scans the field for a high level view of the crop's health.

Then a ground based robot with a multi-spectral camera scans the crops for a per-plant level view. This data is combined to provide a high resolution map of the field's nitrogen levels.

This high resolution map is then used to control the nitrogen application rates, ensuring the crops get exactly the amount of nitrogen they need and not too much. In order to apply the nitrogen with the accuracy needed, a ground based robot or drone can be used.

The drone is much preferred as it avoids crop damage and eliminates soil compaction. This allows the farmer to apply "little and often" which is the proven way to maximise Nitrogen Use Efficiency (NUE)."

Surveillance and Professional Services

At first glance, this sector may not seem like an obvious one for drone use, especially due to the office based nature of much of the work. However, the potential GDP impact and cost savings are considerable and much of this is driven by the use of drones to make building inspection faster, safer and cheaper than traditional approaches – refer to the Renfrewshire Council case study, above. In addition to asset inspection, we expect that drones will increasingly be used to carry out certain elements of building maintenance such as spraying buildings to clean or otherwise treat the exterior. As well as being beneficial for asset management and maintenance, drone inspection data will continue to assist the Insurance sub-sector with claim evidence and inform premium setting. This data-driven approach may prevent a level of insurance fraud, enabling savings to be passed back to the policy holder.

We also expect drones to play a major role in security and surveillance for this sector, given the significant amount of buildings and other properties. We expect that security drones will be ubiquitous across all sectors by 2030 and cover this use case in the first case study below.

This section closes with an innovative use of drones for auditing which, while not a major contributor to potential GDP uplift, does illustrate the potential for drone digital transformation to deliver in this sector.

Industry sector

Financial, Insurance, Professional and Administrative Services

GDP impact	Cost Savings by 2030
£7.0bn	£3.0bn

Why Send a Human to Do a Drone's Job?

Security cameras are nothing new. In fact, in the UK it is estimated that we have as many as one camera per 14 people in the country. However, the fixed nature of these cameras comes with its downsides. Blind spots and an inability to cover all areas of interest can limit their effectiveness, as can an organisation's ability to effectively monitor the security data that they gather. Drone solutions can address many of these problems and use cases for security drones are now emerging in the UK.

The most common concept on the market right now is the **Drone-in-a-Box**, which is exactly how it sounds. The drone is housed in a "box" until it is needed, at which point it autonomously takes off, flies its mission and then lands back in the box. The box is essentially a weatherproof container that protects and charges the drone when not in use.

One example of the **Drone-in-a-Box** concept comes from HeroTech8 who has designed a solution with security in mind. Drone flights from the box can take place on either a scheduled basis or when triggered by security system **IoT** sensors. When the drone is flying a routine scheduled flight, it is able to look for anomalies or changes at a site, flagging anything that looks out of place or suspicious for immediate video stream review or subsequent analysis. If the drone is triggered by an onsite **IoT** sensor, it will take off and fly directly to the cause of the alarm to give the security team "eyes on". The drone can also use real time **AI** to detect suspicious behaviour and track intruder movement around a site. Herotech8 has designed its box to work with a wide range of security systems as well as different drone and sensor types, allowing for straight forward integration with existing security protocols.

It is not currently possible to deploy a **Routine BVLOS** Drone-in-a-Box solution in the UK but this example from Herotech8 and other global examples from companies such as Azure and Airobotics show the considerable potential for this approach. If a different approach to legislation and regulation is adopted, and assuming that public privacy concerns can be addressed, there is likely to be significant future opportunity in this space.

HeroTech8 says:

"At less than the cost of a single full time security personnel, even on a part-time basis, we've observed cost-saving potentials of over 45% OPEX just for medium-sized security teams on critical infrastructure applications and, depending on the nature of the infrastructure asset/facility, the cost-saving potential (% of OPEX) further increases when including parallel industrial inspection activities.

Increasingly, inspection flights are also being executed, to capture high-resolution video and imagery of hard-to-reach structures such as rooftops, stacks and masts that would otherwise have required a drone-operating contractor or risky rooftop/rope-access.

As such, even in this single unit installation, the extensive value that a Drone-in-a-Box solution can provide is very clear.

To provide a real-life example of our solution, a critical infrastructure customer in Europe operates a pair of our systems to provide a patrol of the perimeter every three hours. The system is operating under full "**BVLOS**" (beyond visual line of sight) conditions. These systems are "supervised" with a security guard observing the video feed on a computer and controlling the camera.

However, the real opportunity lies in "unsupervised" drone operations, where no supervision by the customer is required. By removing the human involvement, we can fully resolve the scalability challenge of the business case, allowing for one-to-many or fully automated operations."

Digital Transformation in Stockpile Auditing

Auditing and accounting are still widely viewed as traditional professions, but times are changing.

The profession is at a watershed moment and there is a need for change to respond to the evolving needs of stakeholders and re-establish trust in the quality of the audit. Audit firms need to embrace technology to respond to increasing scrutiny and the continued focus on improving audit quality.

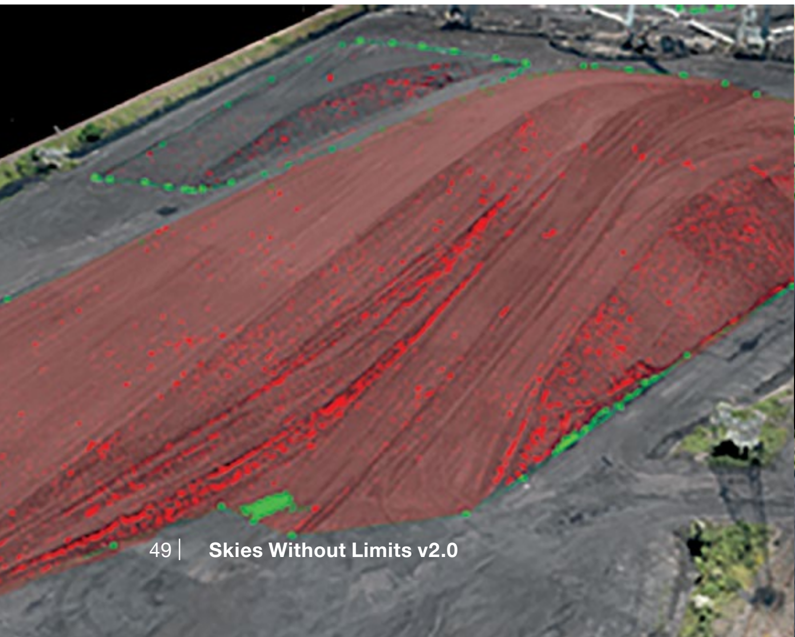
There is also an increase in the number of companies who are using drones in their own operations, usually to calculate the volume of stockpiles such as coal, biomass and aggregates. Auditors need to develop a solution to enable them to test this use of emerging technology. They need assurance that the volumes provided by the client's drone process, or other counting approach, are accurate and complete.

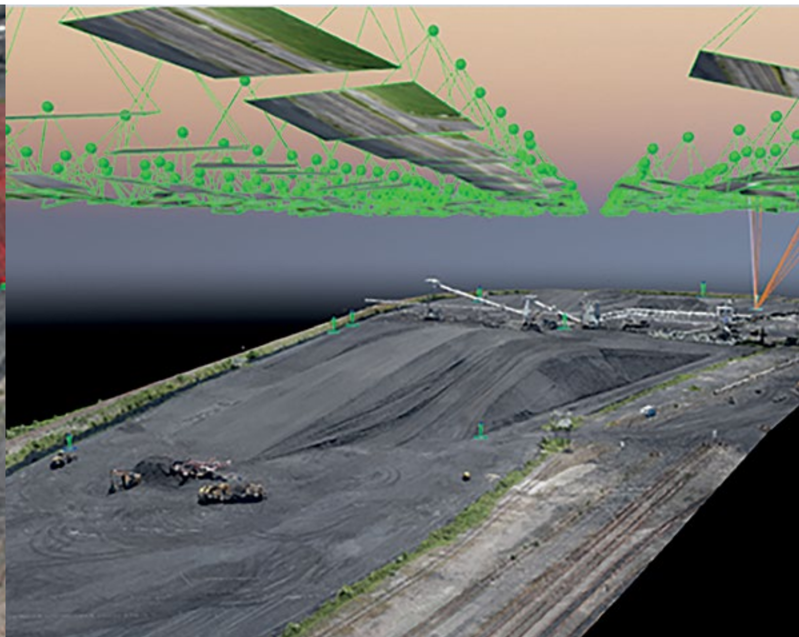
The traditional approach to auditing stockpiles consists of an auditor walking the site and observing the client's own count approach. There is no independent volumetric data gathered. In contrast, a tech-enabled approach involves drone capture of a full volumetric dataset at the same time as the client is flying their own drones or using another counting method. This complete, independent dataset is processed and the results are compared with the client's volumes. Removal of manual processes allows the auditor to focus on analysing the data and providing more value to the audit.

The benefits of this tech-enabled inventory testing approach are significant: increased volumetric accuracy levels as a result of the vast number of data points collected by the drone; health and safety advantages as the data can be collected from a safe vantage point; less disruption to clients as operations can continue on the site given the data is captured from above; and logistical benefits as the audit team have access to accurate digital models of the assets from anywhere in the world.

PwC has been a pioneer of drones in audit and with their first flights carried out in 2018, the use of drones for stockpile auditing is now an established methodology.

Going forward, the digital revolution will continue to pose questions to the audit profession, challenging the way it currently does things and opening up the potential for technologies to increase the quality and efficiency of the audit. Although drone technology is being used to audit stockpile volumes, it is far from the norm and we expect that it will become business-as-usual in the next 5-10 years. There is also a lot more potential for drones and other robotics when we look at the audit of the future. For example, client investment in warehouse drones continues to increase. We might see a day when audit clients are using autonomous drones in their warehouses, with **AI** analysing data in real-time, seamlessly integrated with their warehouse management systems. Such an exciting use of technology will require a very different audit approach, as will the auditing of any AI-driven solutions.





PwC says:

“Our use of drone technology is aligned to International Auditing Standards and to our wider audit vision, which is to deliver the highest quality audit, combining passionate people with leading technology to build trust in society. It is proving to be a game changer for audit teams who are embracing this fresh approach:

Using drones on the first year audit of a large mining client with multiple sites across the UK gave us accurate volume measurements of inventory in a quick and safe manner, avoiding the need to have people climbing over stock piles. Drones are certainly going to be an integral part of our inventory audit approach on this client in future years.”

Construction and Manufacturing

Although one of the smaller areas in terms of GDP impact and cost savings, the Construction and Manufacturing industries generally run on tight margins and any opportunity to drive savings is pursued. The Construction and Civil Engineering sub-sector drives the majority of cost savings in this industry sector, responsible for £1.2Bn (76%) of the total figure.

Drones can be used to survey construction sites, enabling regular reviews of construction progress and offering assurance over the build and its adherence to schedule. Mistakes can also be quickly spotted and rectified. Using drones can also reduce the number of site visits required, reducing HSE risk, cost and environmental impact. Site visit reduction could be due to faster capture (compared to "traditional" approaches) and/or a result of the detailed and compelling, up-to-date visual asset management (see "Data" case study) information available in the cloud.

There are other commercial benefits, for example, using drones to generate an inarguable record of site condition at key points in the project can limit and make dealing with landowner or commercial claims more efficient. According to DroneDeploy, drones could deliver a "52% reduction in time to gather data and a 61% improvement in the data pulled, resulting in a 20x cost savings for some companies".

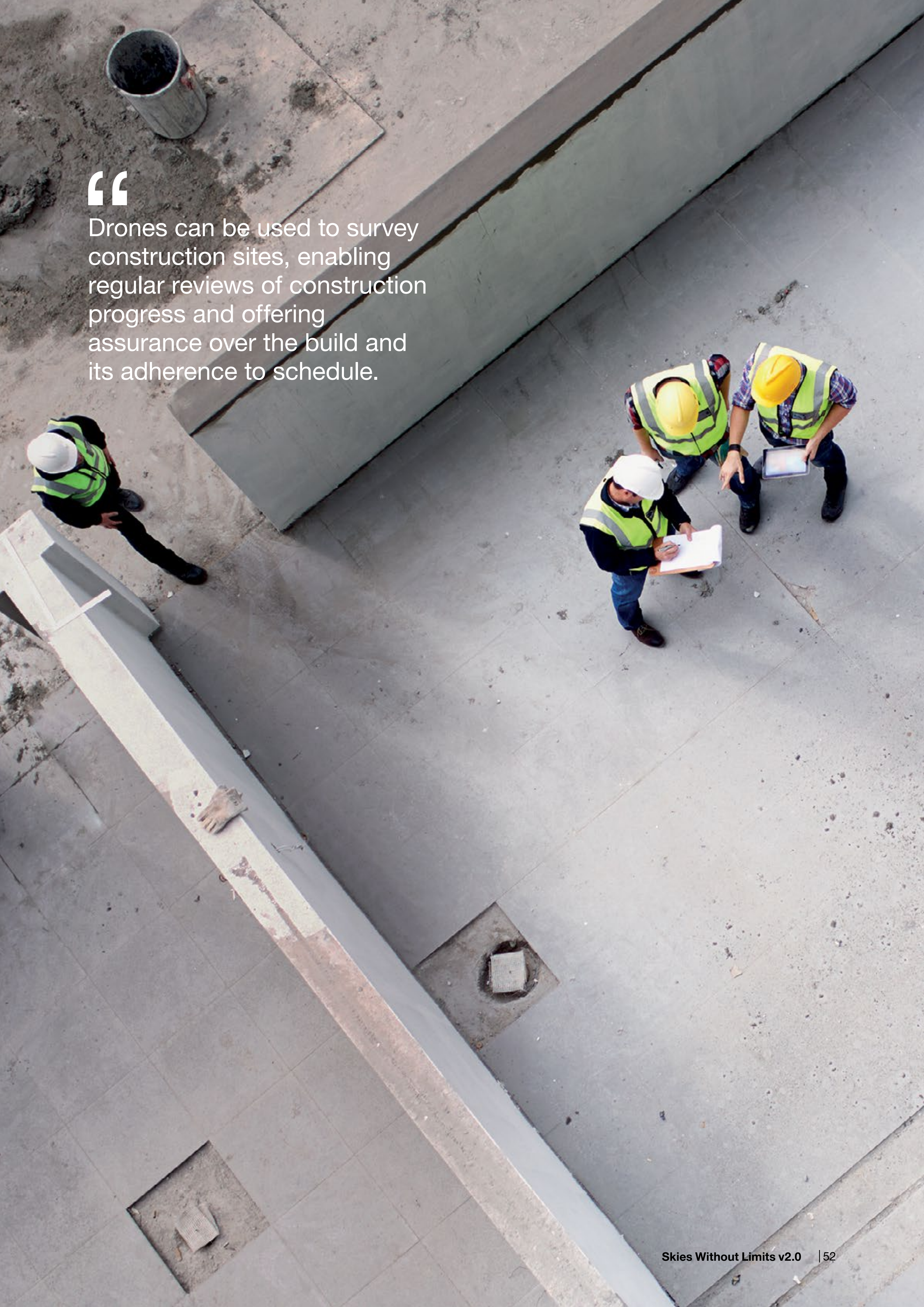
Many UK construction companies already use drones on their big construction projects, and this trend is set to continue towards the end of the decade. In the future, drones may also begin to directly assist with the construction process, with heavy lifter drones that could one day carry "thousands of pounds" of building materials. This could reduce the need for cranes and other heavy machinery on site while improving efficiency and sustainability.

Industry sector

Construction and Manufacturing

GDP impact
£2.8bn

Cost Savings by 2030
£1.6bn



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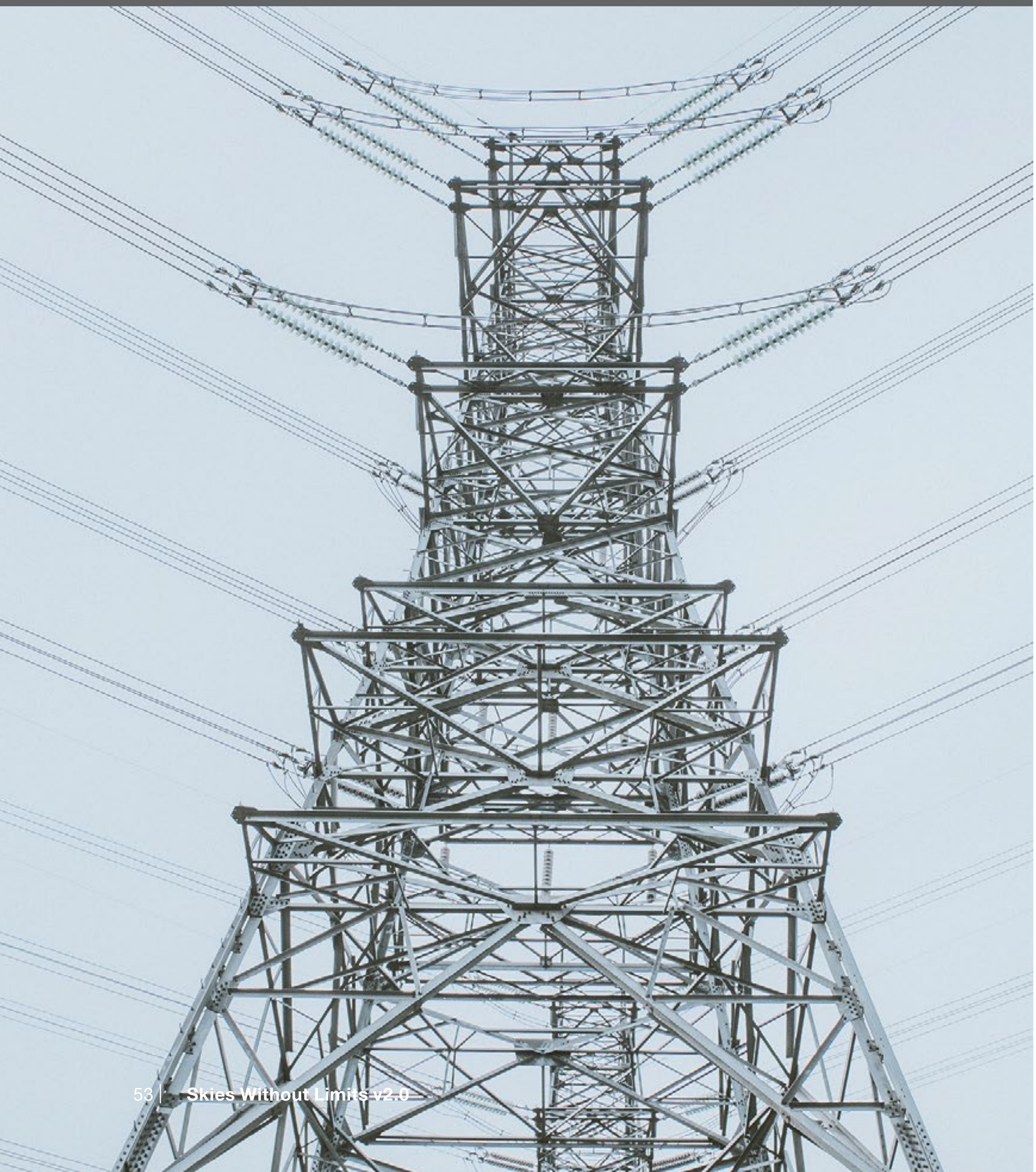
Drones can be used to survey construction sites, enabling regular reviews of construction progress and offering assurance over the build and its adherence to schedule.

5
Appendix



Methodology

In this section we set out the methodology for each of the elements, covering key assumptions and calculation approaches. Note that these calculations feature a number of forward looking assumptions which are inherently uncertain and that we have used a similar "best case" drone adoption curve to the **SWL1** report which, as noted above, requires many challenges to be addressed to unlock the full potential expressed in these figures. Refer also to the "Disclaimer" section below.

Cost Savings

We took the total 2030 net cost savings from the **SWL1** report and scaled this up to reflect various macroeconomic and microeconomic factors, notably wage inflation in sectors impacted by COVID-19 and Brexit. These increases are primarily felt in the *Transport and Logistics* sector where driver shortages have accelerated real wage growth. We only extend the assumption of wage inflation until 2023, where we assume it is 3.4% per annum above the baseline.

The total cost saving figure was then allocated across the different sectors in our economic model, based on our estimate of potential drone use in each sector.

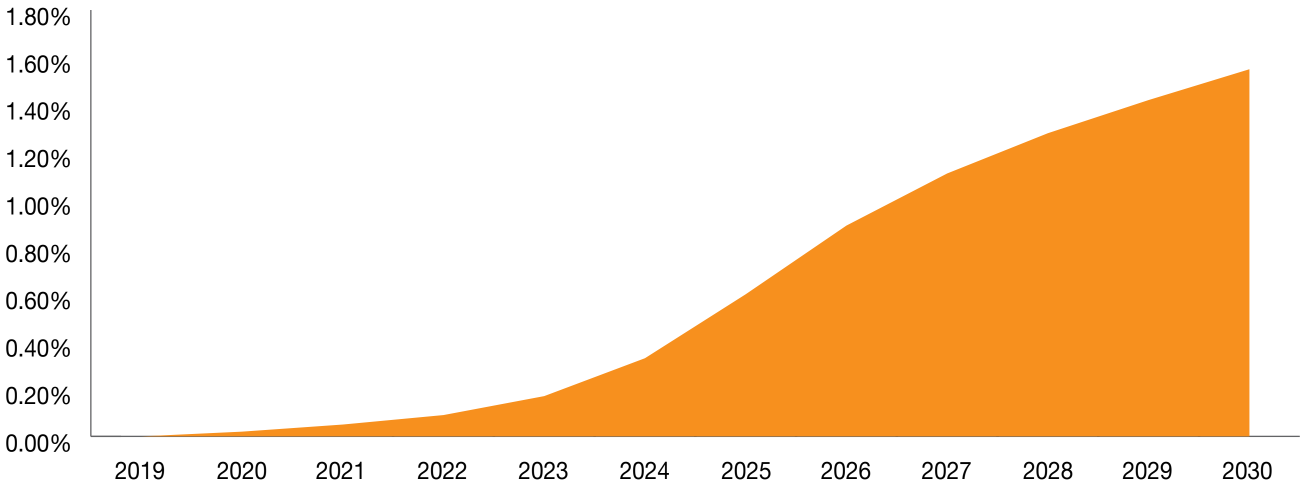
GDP Impact

We used the CGE (Computable General Equilibrium) approach described in the **SWL1** report (pages 21-25), comparing a "steady state" or baseline model of the UK economy with one which we had "shocked" with multi-factor productivity ("MFP") impact of drones, which we derived from the 2030 Cost Savings.

We assume an 'S-shaped' adoption curve of drone technologies, in line with much of the research on the life cycle or technology adoption and innovation diffusion. In practice this means that adoption is slower in the nearterm, before picking up more rapidly when the major obstacles have been overcome before slowing down again as the limit approaches. This S-Curve used in this report is based on the curve used in the 2018 report, although condensed based on fewer years in the modeling period.

The shape of the S-Curve drives the impact on GDP shown in the Figure below. It takes time for the effects of drone adoption to reach the expected impact of 1.6% of GDP by 2030. The economic benefits are likely to be smaller between 2022 and 2024, with the largest ramp up being between 2024 and 2028 and the effects flattening off between 2028 and 2030.

Figure 1: **Aggregate Impact of Drones on UK GDP Against Baseline Forecast, and Profile of Impact, 2021-2030**



Jobs

We took the wage outputs of the CGE in "steady state" and with the drones MFP shock and divided by an average wage figure to estimate the full-time equivalent (FTE) employees associated with each scenario. We subtracted the "steady state" FTEs from the drones MFP shock FTEs to determine the change associated with drone adoption. This gives us the direct effect of 270,000 employees whose jobs would be directly affected by drone adoption. This number of jobs could be higher as many of the workers affected could be part-time.

This approach calculates changes directly occurring in the labour market. In addition, firms should become more profitable as a result of drones being in their supply chain, with drone-enabled solutions cheaper than the alternative, or they may be in the financial sector investing in drone related businesses. This means that they would be expected to create further employment opportunities, we calculate an indirect effect of a further 380,000 jobs created. This figure is derived from the scale of complimentary capital accumulation associated with drone adoption in 2030, i.e. profit is reinvested in the business. These workers will not necessarily be employed in drone related industries or have anything to do with drone operation.

CO2

We estimated percentage CO2e savings by comparing drone-enabled solutions against more "traditional" (not drone-enabled) approaches for multiple use cases such as inspection, survey and last-mile delivery. In the main, CO2e emission savings were driven by reduced vehicle usage due to the efficiency of drone-enabled solutions resulting in fewer trips to site (e.g. inspection) or by removing the requirement for vehicles (e.g. last-mile delivery).

We then took the baseline CO2e emissions (in kg) under the "steady state" CGE scenario in 2030 and estimated the proportion of total sector emissions that could be associated with drones. The sectoral, drone-specific CO2e emission figure was then factored down by the percentage CO2e savings derived from the drone use case distribution in each sector to give the total CO2e emission reduction associated with drone adoption in 2030. We divided the total CO2e emission reduction figure by the average annual emissions for a diesel car to put it into perspective.

Drones

We took the number of entities with **Commercial Drone** permissions at the end of 2020, multiplied these by our assumption of average drones per entity and then scaled these numbers from 2021 to 2030 using the S-Curve. This total figure was then apportioned to sectors on the basis of net cost savings.

Sector Breakdown

In this Section we explore the GDP results and our calculations of cost savings in a more granular form, breaking them down into 24 industrial sectors. From the chart below it can be seen that in a small number of instances, some sectors (e.g. gas, energy, renewables) experience cost savings that do not necessarily translate into GDP gains.

There are three compounding effects associated with the GDP gain in our modelling.

Firstly, As drones are introduced to a business they will make workers more productive and complement their skills. In some instances, they will directly replace labour. But generally, they contribute to an overall improvement in productivity.

The direct impact on GDP of this productivity improvement is that more output is produced with less inputs. There are three potential outcomes that are associated with this direct impact:

i. Output increases, workers are paid more to account for overtime, higher skills associated with them being able to produce more with drone technology. GDP increases.

ii. Output increases and profits increase. GDP increases.

iii. Output stays the same (i.e. demand does not increase, but the firm produce the same with less). Can actually lead to wage bill decreasing and GDP decreasing.

Secondly, some of these cost savings will be passed on to consumers in the form of lower prices and some will be absorbed into higher profits. This outcome very much depends on where the sector sits in the supply chain and the market power it has. Some sectors may be forced to pass on cost savings in full and, while output remains the same, their wage payments could decline as a result of needing a smaller workforce, but their profits would not increase either as they are not able to keep hold of the cost savings. This would lead to a fall in GDP.

Finally, some sectors may have resources competed away from them (investment, workforce). Others sectors may have more initial profits, enabling them to pay higher wages to attract more workers into their respective sectors. GDP falls in the sectors that have resources competed away from them. It rises in the sectors that have been successful in competing.

In a sector such as *Postal and Courier* services we see large cost savings but much smaller GDP gains. This is a highly competitive sector where savings are passed on to consumers (could be business to business consumers such as large retailers) and wages are relatively low (so difficult to retain workers with salary increases).

In *Upstream Oil and Gas* we see a small decline in GDP, in this sector we see labour being attracted out of the sector to work in other industries in exchange for higher wages. However, given the fluctuations in the Oil and Gas prices that have happened as a result of the war in Ukraine, this instability may reverse this result. If the status quo was maintained, this would be a sector where drone adoption will not positively impact sector GDP, although it will still deliver cost savings.

Figure 2: **GDP Impact and cost savings per Industry Sector in 2030 in £bn**

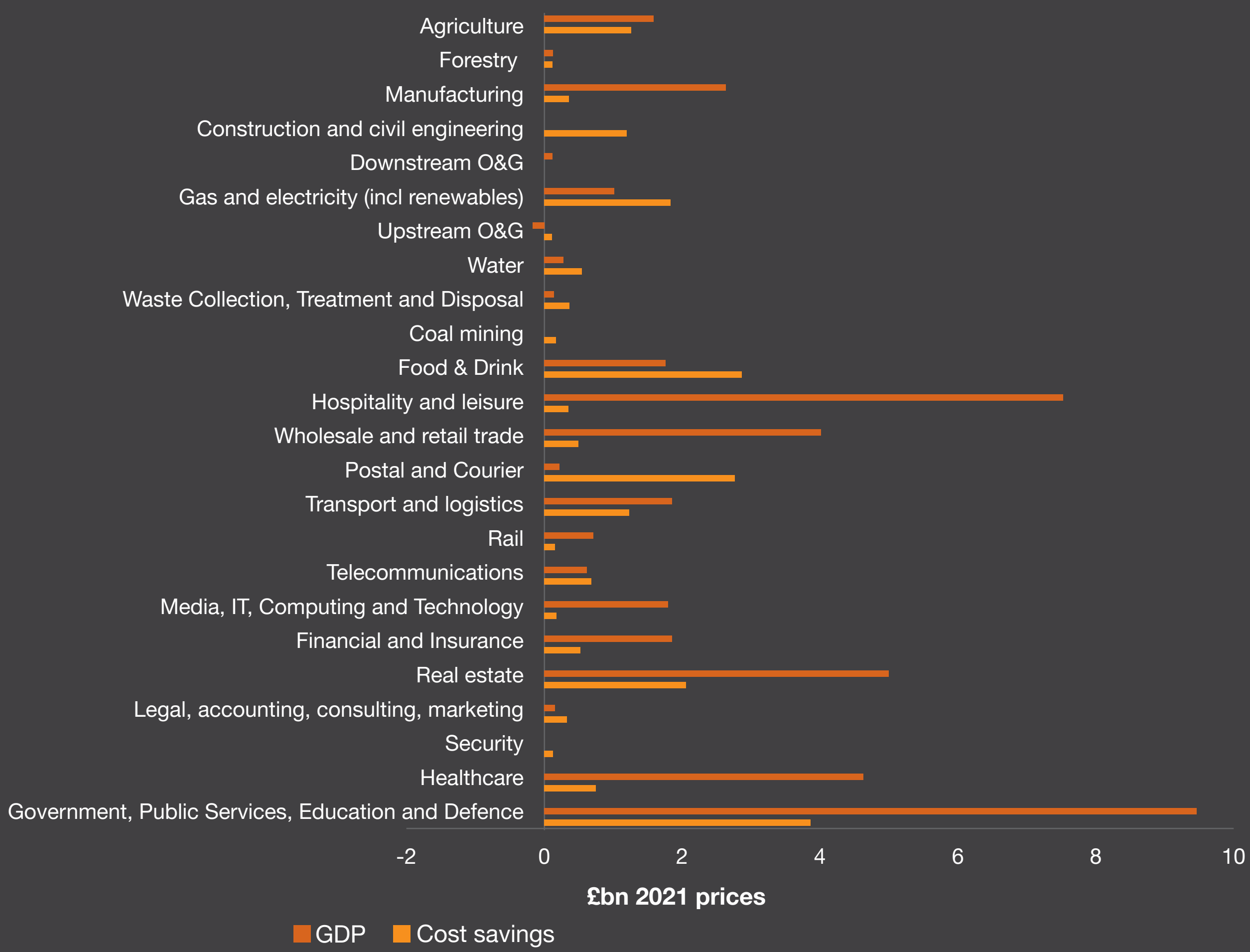
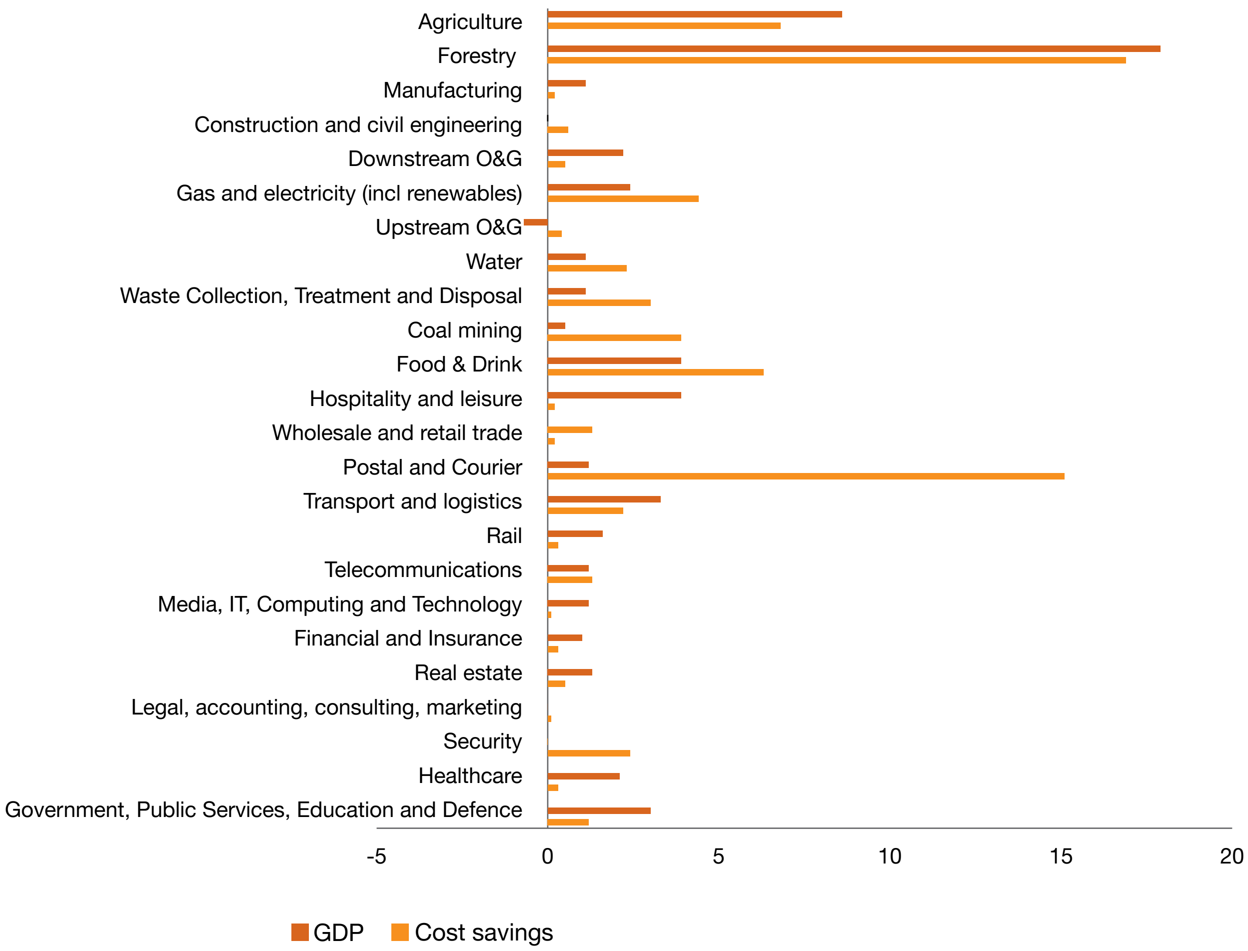


Figure 3: **GDP Impact and Cost Savings in Percentage of 2030 GDP**



Disclaimer

It is not possible to project future level of economic activities with certainty. Many macroeconomic factors influence this, including some which are inherently difficult to predict, such as changes in geopolitical conditions, business sentiment and consumer tastes. As such, all such projections need to be treated as indicative and uncertain, and management judgement needs to be exercised if they are taken into account when taking business decisions. Nevertheless, businesses need to make plans based on reasonable views of likely future trends in macroeconomic variables, and the use of appropriately researched and evidenced projections should aid this.

We accept no liability (including for negligence) to anyone in connection with this document. In this document, we have carried out projections for economic activities up until 2030. Due to the inherent uncertainties of such an exercise, the methodology and assumptions applied to derive these projections should not be considered the only possible one for such purpose and the projections will not be the only possible projections of future events. Therefore, we give no assurance and will accept no responsibility for the achievement of any projections presented here.

Use Case Definitions

Dominant		Examples (not exhaustive)
Inspection	Capture of detailed images (visual and/ or thermal) to enable inspection against a given inspection standard/ code to assess asset condition. Includes external and internal inspection	• Defect detection • Defect monitoring • Record of condition • Detection of hotspots
Survey	Rooted in traditional land survey, this category involves the measurement of the subject, usually to a stated accuracy using sensors such as images, laser scanning, multispectral, hyperspectral. Use of drones for gas detection and environmental monitoring. Includes above ground, underground and indoors	• Topographic survey • Mapping • Volumetric calculation • Crop health assessment • Vegetation encroachment • Cattle monitoring • Scan to BIM (3D "as built") • Asset visualisation • Gas detection • Environmental disaster monitoring • Leak detection
Delivery Middle Mile	Drone delivery that delivers the package to a staging point, rather than the end recipient, typically to a depot or warehouse	• Consolidated bulk shipment • Mail
Delivery Last Mile	Drone delivery that results in delivering the package to the end recipient, often a consumer	• Medical samples • Ship to shore • Takeaway • Grocery delivery • Parcel/ package delivery
Surveillance	Use of drones to monitor an area or a subject to detect or react to notifications of suspicious behaviour or to provide situational awareness	• Perimeter • Search and rescue • Situational monitoring

Other		
Imagery	Simple capture of stills (oblique, 360, etc) and video	• Stills • Video • Live stream
Physical	Physical applications not covered in the delivery heading such as non-destructive testing and crop or building spraying	• Non-destructive testing • Spraying (crops/ buildings) • Seeding • Harvesting • Taking samples • Drone "light" displays • Powerline "stringing" • Ground Penetrating Radar • Sonar (bathymetric)

Glossary of Terms

AI – Artificial Intelligence	A system capable of making its own decisions based on the data that it is presented with. This could be onboard a drone itself, or part of the wider drone ecosystem.
Autonomous/ Autonomy	Autonomous drones are able to fly and navigate without human input, often due to complex algorithms and navigation systems associated with their use. There is a key difference between "autonomous" and "automatic", with the latter tending to relate to flights that follow a pre-programmed route in a set location. Autonomous drones could take off, fly, avoid obstacles and subsequently land in a location they had never seen before without any difficulties.
BVLOS – Beyond Visual Line Of Site	This acronym refers to drone flights that take place out of sight of the human operator. This can include scenarios when obstacles obstruct the drone pilot's view and situations where the drone is being flown many miles away from the operator's location.
CAA – Civil Aviation Authority	The UK's aviation regulator, responsible for overseeing all aspects of civil aviation in UK airspace.
CGE	Computable General Equilibrium modelling approach.
Commercial Drone(s)	Drones that are used for commercial purposes (the focus of this report) as opposed to recreational purposes.
Detect and Avoid	Technology that enables the drone to detect conflicting traffic or other hazards and take action to avoid contact.
Drone Autonomy	See Autonomous / Autonomy above.
Drone-in-a-Box	A system where a drone is permanently housed in a box at a given location, ready to fly whenever needed. These systems tend to be utilised when regular, scheduled flights from the same location are needed.
Electronic Conspicuity	Technology that allows for different airspace users to broadcast their positions and communicate with one another. This technology underpins many of the more advanced drone use cases in this report.
Future Flight Challenge	Part of the Industrial Strategy Challenge Fund, a £300M (government/ industry matched) initiative to drive the future aviation technology in the UK. "The challenge aims to bring together technologies in electrification, aviation systems and autonomy to create new modes of air travel and capability. It will: • create the aviation system of the future • increase mobility, improve connectivity and reduce congestion for people across the UK • advance electric and autonomous flight technologies to help the UK reach its net zero target • drive technology investment to the UK by increasing UK manufacturing and service opportunities."

Glossary of Terms (Continued)

Future Flight Challenge Report	A UKRI/ PwC socio-economic study looking at opportunities for developments in aviation technologies which could boost the UK economy and deliver wider societal benefits.
Industry Perception	The views of business leaders and the general feeling amongst an industry as a whole on particular subject matters, such as drone technology.
Inspection	A drone use case that typically involves flying close to an asset to take high quality imagery of particular asset features. These images will typically be assessed and rated based on the asset condition, enabling decisions to be taken on whether the asset needs to be repaired or replaced.
IoT	Internet of Things. A connected network of devices that all rely on an internet connection to communicate with each other.
Last Mile Delivery	Delivery of items directly to the end recipient.
MFT	Multi-Factor Productivity.
Middle Mile Delivery	Movement of goods between locations, such as from a warehouse to a distribution centre.
Public Perception	The views of individuals within society and the general feeling amongst the public as a whole on particular subject matters, such as drone technology.
Remote Piloting	A subset of **BVLOS**, remote piloting refers to a situation where a drone (usually a multi-rotor) is actively controlled by a pilot who is at a remote location in a manner analogous to **VLOS**, e.g. for close visual inspection of infrastructure. This in contrast to the type of **BVLOS** where a drone is predominantly flying a fixed route based on waypoints and there is little active pilot input.
Routine BVLOS	Beyond Visual Line Of Sight flights that a drone operator can conduct whenever required, without the need to go through approval from the CAA each and every time.
S-Curve	Typical technology adoption curve, refer to the “Methodology” Section above, under “GDP Impact”.
Segregated Airspace	Areas of airspace that are shut to airspace users other than those for which the segregated airspace has been established. This allows for trials of more advanced drone operations without the risk of the drones colliding with other airspace users.
Survey	A drone use case that typically involves flying a drone over and around an asset to capture multiple overlapping images from different angles. The images can then be combined in photogrammetry software to create an orthophoto or 3D model that can be used for surveying purposes.
SWL1	Skies Without Limits, the original 2018 report.

Glossary of Terms (Continued)

Trust in Drones Survey	A 2019 PwC study looking at the public and **Industry Perception** of drone technology and the different use cases that drones are capable of.
Unsegregated Airspace	Areas of airspace that are open to all airspace users.
UTM – Unmanned Traffic Management	A similar concept to traditional air traffic control, but with all airspace users integrated. Underpinned by other areas such as electronic conspicuity and Detect and Avoid.
VLOS – Visual Line Of Site	Most drone operations in the UK are required to be flown within the pilot's view. This needs to be unobstructed and not aided with any other tools such as binoculars. Typically this would mean less than 500m from the pilot.
VTOL – Vertical Take off and Landing	A type of drone that brings both the benefits of a quadcopter and fixed wing into one. This means the drone can take off on the spot without a runway, but fly further distances more efficiently.

Further Reading

Legislation and Regulation:

2017 DFT consultation Unlocking the UK's high tech economy: consultation on the safe use of drones in the UK government response

2019 consultation Taking flight: the future of drones in the UK government response

2021 Air Traffic Management and Unmanned Aircraft Act Impact Assessment

2021 Future of Flight consultation Future of transport regulatory review: future of flight

Perception:

NATS Aviation Index Aviation Index 2021

CAA Drones Awareness Tracker PowerPoint Presentation

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SPS Design RITM7885932 (05/22).