frontier economics

GEOSPATIAL DATA MARKET STUDY

Report for the Geospatial Commission

September 2020

Geospatial Commission

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EXECUTIVE SUMMARY

Context and background

The capabilities offered by geospatial data and location-based insights are no longer confined to the periphery of the UK economy. Geospatial data, otherwise known as location data, plays a significant role for businesses, individuals and the public sector and drives economic value. Geospatial data is increasingly being collected via a variety of means including location-aware devices and connected sensors. It has transformed the lens through which decision making is carried out and has enabled a new generation of consumer services that put location at the forefront of our lives. Consumers currently use a range of services that rely on geospatial data. These include fitness applications which track exercise activity, in-car navigation systems and insurance offerings that are informed by location data.

Frontier Economics was commissioned by the Geospatial Commission to carry out a detailed economic study of the size, features and characteristics of the UK geospatial data market. The Geospatial Commission was established within the Cabinet Office in 2018, as an independent, expert committee responsible for setting the UK's Geospatial Strategy and coordinating public sector geospatial activity. The Geospatial Commission's aim is to unlock the significant economic, social and environmental opportunities offered by location data. The UK's Geospatial Strategy (2020)[1] sets out how the UK can unlock the full power of location data and take advantage of the significant economic, social and environmental opportunities offered by location data.

This report sets out the results of our work, informed by an extensive data collection exercise and engagement with participants across the market. The report also builds on previous studies that have explored the value that some forms of geospatial data bring to specific sectors.[2] Our approach goes further by exploring the dynamics of the economic market for multiple types of location data and services, including how value is being generated from new sources of location data.

The findings and evidence presented throughout this report illustrate how the market has been transformed via an evolution in data collection mechanisms. Technology has enabled a substantial amount of value to be generated from non-traditional sources of location data, such as data gathered through crowdsourcing or as a by-product of company activity in other markets. Location-based services, powered through smartphone apps and other location-enabled devices, are now

[1] Unlocking the power of location - The UK's geospatial strategy:
https://www.gov.uk/government/publications/unlocking-the-power-of-locationthe-uks-geospatial-strategy

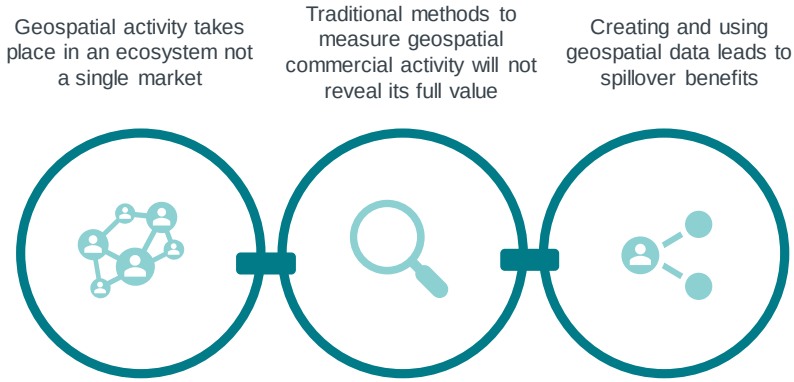
[2] For example, analysis of private sector geospatial use cases published by the Cabinet Office (2018) suggests government could unlock between £6 and £11 billion per year of economic value. Also, a UK space industry study (London Economics, 2019) explored geospatial services like earth observation, positioning and navigation, and Deloitte (2017) concluded that Transport for London (TfL) is generating up to £130 million a year in economic benefits and savings through its release of its open geospatial data. Other work has focused on the importance of geospatial data technologies, such as the Global Positioning System (GPS) and the Global Navigation Satellite System (GNSS). See for example: https://www.bbc.co.uk/news/business-49985957

an integral part of the consumer experience. As technology continues to improve, and new forms of location data continue to be generated, this timely assessment of the geospatial market can help drive further economic growth by identifying opportunities for the UK that can be unlocked.

Market characteristics

During the course of our extensive research into the geospatial market, we observed three distinct characteristics of the geospatial data market (Figure 1). These three characteristics set the foundations for our conclusions on the economic dynamics of the market, which present an opportunity to generate additional value through informed policy-making.

Figure 1 Geospatial data market characteristics



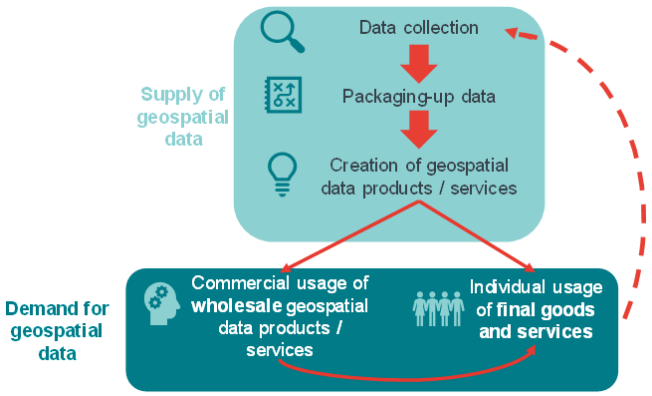
Source: Frontier

1. **It is an ecosystem rather than a traditional market structure**

Given that geospatial firms offer a range of diverse products and services across multiple industries, it is not appropriate to view geospatial activity as taking place within a single economic market (Figure 2).

Activity is better visualised as a geospatial ecosystem containing individual submarkets, based on specific groups of products and services. We make a broad distinction between "supply" of geospatial data and "demand" within any specific geospatial market within the ecosystem.

Figure 2 Ecosystem illustration



Source: Frontier based on a review of existing evidence and sectoral engagement

The supply side can be sub-divided into value-adding stages covering generation of data, transformation of that data and linking with other forms of information. Some supply-side organisations specialise in a niche within this value chain, while others span the entire spectrum of activities.

Geospatial products and services will also vary in terms of their granularity. In some cases, geospatial data will be aggregated. For example, transport authorities can learn about patterns of demand for public transport by examining information on aggregated user journeys. On the other hand, more targeted aggregation of geospatial data may be used to inform personalised advertising, which is informed by a person's previous movements. These two data requirements will likely be served by different supply-side organisations and therefore occupy different positions within the overall data ecosystem.

Some goods and services are entirely geospatial in nature such as a database of addresses and associated locations. Other goods and services include a geospatial element in addition to many other components such as a transport planning smartphone application which relies on geospatial data as well as a range of other hardware and software.

We found evidence that the demand side of the ecosystem is not confined to one area of the economy. Widespread adoption of geospatial data products or services could contribute to higher levels of productivity via more efficient supply chains or more accurate resource allocation. A significant proportion of value from geospatial data will come from more widespread adoption of geospatial data products and services by firms across a large number of sectors. For example, in some instances the usage of products and services generates additional data that is fed back to the data collector. These can contribute to network effects, where the quality of the upstream supplier's offering is related to the number of user, such as when a geospatial service relies on crowdsourced data, it becomes more accurate as the user base increases.

As we describe below in greater detail, evidence from the interviews suggest that some coordinated policy action may be needed to achieve more widespread adoption. This could include improving existing data infrastructure or addressing other specific barriers to adoption such as inflexible legacy IT systems. This is in keeping with previous analysis carried out by the Cabinet Office (2018) which illustrated how multiple sectors could derive value from greater adoption of geospatial data.

2. **Current industry definitions do not adequately capture the geospatial market and several large firms span geospatial and other digital areas**

Geospatial data forms a key part of the commercial activity for a wide range of companies that operate across multiple sectors in the economy. This makes it challenging to estimate the true value of geospatial data.

This report has attempted to produce an estimate of the value of the UK geospatial market by capturing the turnover of a subset of the wider ecosystem. Namely, those companies for whom the supply and provision of geospatial data is a core part of their product or service offering.

Major demand-side users of geospatial data, such as retailers and marketing companies, and large digital technology firms like Apple, Google and Amazon, are

a key part of the broader geospatial ecosystem. However, the ecosystem characteristic of the geospatial market means that the activity and turnover of these companies overlap with multiple other markets. Taking an approach that focuses on where geospatial data is a core part of the company's product or service offering provides a more robust estimation of value. This also demonstrates the difficulty in attempting to define a market which has activity that spans multiple sectors, as has been found in digital industries (House of Commons Business, Innovation and Skills Committee, 2016).[3]

Under this framework, we were able to identify almost 2,000 such geospatial firms operating in the UK. The data suggests that this subset of geospatial firms are dispersed across many sectors and industries, reflecting the ongoing incorporation of geospatial insights across the economy as a general purpose technology. The technology, professional services and engineering sectors, in particular, contained the highest number of geospatial firms. This is in keeping with the private sector geospatial use cases identified previously by the Cabinet Office (2018)[4].

We were able to explore multiple facets of these 2,000 firms. A conservative estimate of value suggests that geospatial accounted for over £6 billion of turnover in 2018[5]. This estimate excludes the large digital technology firms like Apple, Google and Amazon. For these firms, geospatial data underpins a significant amount of their activity but it is not possible to estimate the proportion of revenue that can be attributed to its use. To give a sense of scale for the value we have not included in our estimate, we looked at the total size of the digital technology market in the UK and apportion some of this to geospatial data. This is relevant given how cross-cutting and embedded geospatial data is throughout the economy, including the digital technology market. If even 5% of turnover in this market were attributed to geospatial data, this would correspond to £9.2 billion[6]. Furthermore, just 5% of the worldwide annual R&D spent by a small number of these large digital technology companies like Apple, Google and Amazon are estimated to be about £3 billion.

In addition, the figures quoted above do not represent the entire economic contribution of the geospatial ecosystem, as geospatial organisations will generate value for a range of other economic actors and individuals. This will include time saved by consumers who can make more informed decisions when they have access to geospatial data products and services. As a result, estimate likely represents a fraction of the total economic contribution of the geospatial ecosystem.

Our data shows that the ecosystem is growing as new firms continue to enter this space. We found that 55% of the geospatial firms that we identified were incorporated in the last ten years and that the average annual growth over this period has been 8%.[7]

[3] https://publications.parliament.uk/pa/cm201617/cmselect/cmbis/87/87.pdf

[4] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/733864/Initial_Analysis_of_the_Potential_Geospatial_Economic_Opportunity.pdf

[5] We use 2018 turnover data as 2019 data is less complete at the time of our analysis

[6] Size of the UK technology market taken from Technation EY report https://technation.io/wp-content/uploads/2018/05/Tech-Nation-2018-press-release-1.pdf

[7] Incorporation dates have been used to identify when new companies are created. These statistics reflect the 86% of companies identified that we were able to match to administrative data.

These firms are also distributed geographically with the highest concentrations in London and the South East with emerging clusters of geospatial data activity in Edinburgh, Cambridge and Belfast.

We were able to collect employment information for two-thirds of these firms which collectively employed over 115,000 staff. Employment rose on average by around 45% a year (from around 20,000 in 2009 to over 115,000 in 2019).[8]

The size of the ecosystem can also be captured through data on fundraisings and grants. Looking at the SME companies identified through the Beauhurst[9] platform, we found that the number of fundraisings had an annual growth rate of over 20% over the past ten years and the growth rate of the value of these fundraisings was approximately 40%. Furthermore, for the geospatial projects identified in UK Research and Innovation (UKRI) data,[10] the number of grants per year grew by an average of over 90% from 2009 to 2019, and the value of grants grew from £2 million in 2009 to over £61 million in 2019.

The ecosystem is constantly developing and changing with new technology and our estimates should therefore be viewed as illustrative and indicative only.

3. **The value of creating and using geospatial data spills over**

Like many other forms of data, the value of geospatial data is not limited to the data creator or data user. Value from using geospatial data can be subdivided into several different categories, based on who the value accrues to:

- **Direct use value:** where value accrues to users of geospatial data. This could include government using geospatial data to better manage public assets like roadways.
- **Indirect use value:** where value is also derived by indirect beneficiaries who interact with direct users. This could include users of the public assets who benefit from better public service provision.
- **Spillover use value:** value that accrues to others who are not a direct data user or indirect beneficiary. This could, for example, include lower levels of emissions due to improvement management of the road network by government. The benefits of lower emissions are felt by all of society even those who do not use the road network.

As the value from geospatial data does not always accrue to the direct user of the data, there is a risk of underinvestment in geospatial technology and services. Our £6 billion estimate of turnover for a subset of geospatial firms in 2018 does not take account of these wider economic benefits that "spill over" across the UK economy, and generate additional value. As such, the value that geospatial data delivers is likely to be significantly higher than we have estimated and is therefore an area for potential future investment.

8 This is based on employment data drawn from multiple data sources, using headcounts.

9 https://platform.beauhurst.com/

10 Which tracks grants awarded for R&D and innovation projects.

Economic dynamics

The three characteristics set out above provide the foundations for our ten conclusions into the economic dynamics of the market. These findings present a detailed evidence base to inform the Geospatial Commission in its approach to supporting the market to generate additional value to society.

1. **Certain emerging geospatial data segments may have relatively few suppliers and buyers (a "thin" market).** This can make price setting difficult for suppliers if they cannot benchmark against other similar service offerings. It can also limit interest from potential users who lack information about a suitable price to pay. This is observed in multiple segments. For example, mobile phone and Global Positioning System (GPS) data can provide insights into aggregated mobility patterns. However, some potential buyers of this data can lack comparative information on prices paid for similar data or services. This can make it difficult for potential buyers to assess value for money and for sellers to stimulate more demand.
2. **There are potential benefits from reuse of privately collected geospatial data that can accrue widely.** For example, this type of data can inform the development of future infrastructure by providing insights into journey patterns. This data can be collected via non-traditional mechanisms, such as crowdsourced information from a large number of connected vehicles, or data generated as a by-product of activity in other markets, such as exercise tracking applications. Therefore, greater sharing of geospatial data can generate economic and social value. However, substantial investment is needed to collect certain types of data and the potential returns can be uncertain. As a result, commercial geospatial activity can follow the pattern of intellectual property business models. Even though the cost of providing access to this form of geospatial data may be low, the collector needs to be rewarded for making the risky investment, which may result in a unique market advantage. Incentives for data sharing that encourage sharing of commercially collected data will need to be created. This is beneficial for society while still allowing those private sector data holders to recoup their investments and incentivise ongoing data collection. In other cases, the commercial sensitivity of certain types of data may mean that providers are unwilling to share regardless of the price or incentive offered, especially if they view the recipient as a potential competitor.[11]
3. **As the geospatial data market operates as an ecosystem across a number of different industries, conclusions about competition within the private sector will vary for different parts of the ecosystem.** We were told by some market participants (such as developers of consumer-facing applications which incorporate a mapping interface) that end-user familiarity with established mapping platforms can be an important commercial advantage for some mapping providers. This may, in some cases, lead to the development of strong commercial positions amongst established mapping providers. Previous work has highlighted how the collection of location data via mapping services allows

[11] This reluctance to share data was also noted by the CMA's (2020) conclusions as part of their online platforms and digital advertising market study.

those providers to operate more effectively in other related digital markets, such as advertising.[12]

4. **Public sector organisations that provide geospatial data and services also operate across multiple areas of the geospatial data ecosystem, and there are often clear economic rationales for their involvement.** However, there is evidence that remits given to some public sector bodies may be crowding out private sector activity, for example where the public sector provides a downstream service underpinned by data which they have legitimately collected and which other organisations have difficulty accessing.
5. **Geospatial data products and services that are currently available are not always being used even when they can add value.** This is in part due to a lack of demand-side awareness of the value that geospatial data can bring. For example, we were told that, in some cases, policymakers were not incorporating available geospatial insights into their decision-making process as they were unaware of the value it could offer. In other cases, demand-side organisations are aware of the value of geospatial data but face barriers to successful implementation, such as inadequate data infrastructure or outdated IT systems.
6. **Access to finance is not consistent across all segments of the ecosystem. For example, there appears to be more competition between funders for companies at early stages of funding compared to those that are more mature.** Our analysis of comparable sectors suggests that this is not atypical and is broadly in keeping with the pattern we see in other firms classified within related sectors, where the vast majority of fundraising occurs at earlier stages of start-up development. However, there may still be value in broadening the supply of current geospatial funding sources. The observed patterns of funding may, in part, be due to wider trends in funders joining together and forming syndicates at later stages of start-up funding rather than competing with each other.

7. **Providers are aware of their need to comply with privacy regulations in relation to geospatial data and of the ethical challenges in relation to the use of location data.** These ethical challenges apply primarily in the context of information on the movement and location of people. They need careful consideration as certain forms of geospatial data can be used to identify individuals. In other cases, geospatial data is used to highlight aggregate movement patterns. For example, information on movement patterns can be collected via mobile network data when handsets interact with mobile masts or when GPS data is harvested via mobile phone applications. As with other forms of data, market participants would welcome further clarity around whether the collection method for certain types of location data (especially GPS data harvested from mobile phone applications) requires further safeguards to prevent any risks to privacy and maintain consumer confidence. A balance needs to be struck as excessive intervention in this area could have unintended consequences such as discouraging data usage and stifling

[12] See for example CMA (2020): https://assets.publishing.service.gov.uk/media/5efc57ed3a6f4023d242ed56/Final_report_1_July_2020_.pdf

innovation. It may be that development of a framework for the ethical usage of geospatial data could help to drive further usage.

8. **Numerous stakeholders reported that geospatial skills are becoming essential components of a wider range of skill sets, particularly data science capability, of which there is a shortage.** In particular, we were told that it is very difficult to find candidates with a combination of geospatial expertise, data science capability and non-technical/soft skills. Overcoming these shortages may require geospatial skills to be included in existing data education offerings and new data career pathways to be developed. These pathways could include dedicated geospatial apprenticeships, for example.
9. **Commercial organisations want to access public sector geospatial data via flexible and modern mechanisms that allow them to pay according to the volume of usage and only access specific data attributes of interest.** High upfront costs for buying and hosting geospatial data can be an access barrier. For example, we were told that users want to access data via machine-readable Application Programming Interfaces (APIs) that enable them to pay in line with the amount of data they use and also to hone in on specific data attributes of interest. Access to public sector data can also be limited when the organisations which have collected and hold such information are not set up or incentivised to provide commercial geospatial products. This can occur, for example, when valuable geospatial data is generated as a by-product of another administrative process such as payment of subsidies.
10. **The quality of public sector data is generally high. However, the provision of local authority data can be inconsistent across certain areas.** For example, we were told that different local authorities store data in a variety of different formats, and also have their own access arrangements in place. This can increase the time and effort required to examine local data.

1 INTRODUCTION

Geospatial data underpins significant economic value in the UK and offers the potential for unlocking substantial additional value through new and innovative use cases.

The Geospatial Commission was established to help unlock this high-value activity. Frontier Economics was appointed to assist the Geospatial Commission by providing insights into the participants within the geospatial data ecosystem and market dynamics. Through this exploration of the current functioning of the geospatial data market, the Geospatial Commission's aim is to help the market to work efficiently and effectively for current and future users of geospatial data and services. Findings from our study highlight existing opportunities for the Geospatial Commission to add future value.

This section frames our study by providing an overview of what is meant by geospatial data and what existing evidence has signalled about the value and importance of that data. We also provide a summary of the role of the Geospatial Commission and the specific terms of reference for this work.

1.1 What is meant by geospatial data?

Geospatial data describes ***where*** places, objects and people are. It takes many different forms and can relate to specific building addresses, larger geographic areas, geology or the location of people. It also has different levels of accuracy: some geospatial data can provide a location to millimetres of accuracy whereas other data will be accurate to hundreds of metres.

In 2018 the United Nations Economic and Social Council adopted a minimum list of global fundamental geospatial data themes.[13] These 14 themes help to illustrate the wide breadth of information which is considered as geospatial.

Geospatial data collection mechanisms change over time. Improvements in technology have allowed new sources of geospatial data to emerge and have transformed the frequency with which new data can be generated. These shed new light on the United Nations Economic and Social Council's themes. For example, mobile network data can provide up-to-date and granular insights on population distributions rather than relying on census distributions, which are costly to produce and can quickly become outdated. Likewise, data ingested by connected vehicle sensors can contribute to our understanding of transport networks.

A list of geospatial data collection mechanisms includes:[14]

- Satellite constellations, airplanes and drones which can collect earth observation imagery and provide navigation and positioning services;

[13] UN Economic and Social Council http://ggim.un.org/meetings/GGIM-committee/8th-Session/documents/E-C20-2018-7-Add_1-Global-fundamental-geospatial-data-themes.pdf

[14] These collection mechanism and other emerging geospatial technologies are discussed further in the Commission's Future Technologies Review (Public, 2019)

- Radar and lidar systems which use radio waves and lasers to assess the location and movement of nearby objects;
- Digitisation and scanning of analogue maps;
- Location sensors embedded in a variety of connected devices including mobile handsets and vehicles; and
- Optical instruments that are used to carry out detailed land surveys.

1.2 What do we already know about the importance of geospatial data across the economy?

Geospatial data already underpins a huge amount of economic activity

Location data has a profound impact on our day-to-day lives and underpins a significant amount of economic activity across a range of different industries. The value that some forms of geospatial data bring to specific sectors has already been explored. However, existing studies tend to focus only on specific industries rather than examining the size, features and characteristics of the geospatial ecosystem as a whole.

For example, the UK space industry, which includes geospatial services such as earth observation and positioning, navigation and timing was the subject of a recent report (London Economics, 2019).[15] This work identified over 900 space-related organisations in the UK with a cumulative income of almost £15 billion in 2016/17. Satellite data was also identified as a major growth area.[16]

A 2017 report found that Transport for London (TfL) is generating up to £130 million a year in economic benefits and savings through its release of its open data (Deloitte, 2017).[17]

Other research has highlighted how geospatial data technologies such as the Global Positioning System (GPS) and the Global Navigation Satellite System (GNSS) currently underpin broad sections of the economy.[18] Without a fully functioning GPS, large and diverse sectors of activity such as transport, farming, construction and surveying could not function (London Economics, 2017).[19]

Farming uses GPS in precision agriculture to optimise route planning for smart tractors and monitoring the locations of livestock.[20] Construction workers operate heavy machinery on the basis of inputs from surveyors, who, in turn, rely on GPS to provide highly accurate locational data.

Existing analysis of private sector use cases suggests the government could unlock between £6 and £11 billion per year of economic value through better use

15 The sector also includes non-geospatial activities in areas such as broadcasting and communications.

16 https://www.gov.uk/government/publications/uk-space-industry-size-and-health-report-2018

17 http://content.tfl.gov.uk/deloitte-report-tfl-open-data.pdf

18 https://www.bbc.co.uk/news/business-49985957

19 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/619545/17.3254_Economic_impact_to_UK_of_a_disruption_to_GNSS_-_Showcase_Report.pdf

20 https://www.nesta.org.uk/feature/precision-agriculture/

of geospatial data (Cabinet Office, 2018).[21] The precise mechanisms that underlie this additional value vary, reflecting the range of different uses geospatial data can have. Use of geospatial data could lever value through reductions in:

- ineffective marketing spends;
- conveyancing costs;
- unplanned construction delays;
- fuel costs; and
- wastage of agricultural resources.

New use cases present additional potential to unlock large amounts of additional value

The studies on the value of space and transport sectors are examples of the existing value of geospatial data in specific sectors. Going forward, geospatial data may be utilised in a range of new ways. For example, it may be used to derive benefits through the realisation of future use cases such as self-driving vehicles, Smart Cities and the Internet of Things. In addition, better use of geospatial data in the public sector (for example, through better routing of emergency services) will create additional economic and social value. This is particularly relevant now for dealing with the response to the coronavirus pandemic.

Geospatial data is included within a variety of products and services that are used by demand-side organisations. In some cases, this data will not be very granular or disaggregated. For example, transport authorities can learn about patterns of demand for public transport by examining information on aggregated user journeys. On the other hand, geospatial data can also be used to inform personalised advertising, which requires a greater level of detail about a specific person, their previous movements and possible interests. These two data requirements will likely be served by different supply-side organisations and therefore occupy different positions within the overall data ecosystem.

We explore some of these new opportunities and use cases in Section 6.

Geospatial data could present an opportunity for the UK to be a world leader

The UK's strengths in cutting-edge research and the intangible economy make it well-placed to be a world leader in data-driven innovation. In particular, geospatial data and technology are a specific source of comparative advantage for the UK (Geospatial Commission, 2018).[22] The UK is home to world-class geospatial institutions which have emerged gradually as a result of investment and the accumulation of expertise. Continued exploitation of geospatial data is essential to ensure that the UK operates effectively within a rapidly changing technological environment. However, there are reasons to believe that government could play a

[21] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/733864/Initial_Analysis_of_the_Potential_Geospatial_Economic_Opportunity.pdf

[22] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/734331/Geospatial_Commission_call_for_evidence_2018.pdf

role in facilitating this development. We explore barriers to the market developing throughout this report.

1.3 The Geospatial Commission

The Geospatial Commission was established in April 2018 within the Cabinet Office as an independent, expert committee.[23] This followed a multi-departmental review which concluded that while the UK does have world-class capability in geospatial data, previous attempts to coordinate data policy have struggled.[24] Therefore, the Geospatial Commission was established to set the UK's Geospatial Strategy and coordinate public sector geospatial activity. The Geospatial Commission has a mandate and budget to drive and deliver changes by working in partnership with others. Specifically, the Geospatial Commission:

- provides strategic oversight of the geospatial ecosystem in the UK, setting geospatial strategy, policy and standards;
- holds the budget for the public sector's largest investment in geospatial data; and
- makes targeted investments in data projects that accelerate innovation and adoption of geospatial data applications.[25]

The Geospatial Commission has a mandate and budget to drive and deliver changes by working in partnership with others. Its approach is therefore to:

- be **use and value driven** – prioritising action in areas where there is evidence of greatest opportunity and impact;
- be **iterative** – achieving its vision by adopting new ideas, learning through pilot projects, and monitoring innovation;
- take a **whole system** approach – technology alone is not enough; leadership, governance, policies, organisations, legal frameworks and skills matter too; and
- be **collaborative and open** – its mission will require collective effort, connecting data, people and systems. Organisations across the nations and regions of the UK, in public, private and third sectors, will play their part. It will learn from, and work with, other countries.

The UK's Geospatial Strategy

The UK's Geospatial Strategy (2020) sets out how the UK can unlock the full power of location.[26] The Geospatial Commission's vision is to have a coherent national location data framework by 2025, where location data can be used as the unifying

[23] https://www.gov.uk/government/organisations/geospatial-commission

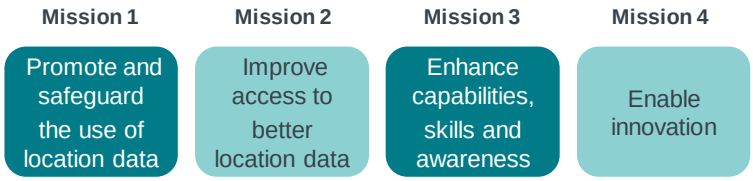
[24] https://quarterly.blog.gov.uk/2018/03/28/location-location-location-tapping-the-economic-potential-of-geospatial-data/

[25] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/894755/Geospatial_Strategy.pdf

[26] According to the most recent global "Geospatial Readiness Index", the UK's geospatial technology sector is recognised as the second most developed in the world, only behind the USA. https://geobuiz.com/geobuiz-report-2019/

connection between things, systems, people and the environment. To achieve this, the Geospatial Commission set out four strategic missions.

Figure 3 UK Geospatial Strategy Missions



Source: Geospatial Commission (2020)

1. Mission 1 – promote and safeguard the use of location data: the Geospatial Commission will provide an evidenced view of the market value of location data, set clear guidelines on data access, privacy, ethics and security, and promote better use of location data
2. Mission 2 – improve access to better data: the Geospatial Commission will streamline, test and scale the development of new and existing location data, ensuring it is findable, accessible, interoperable, reusable and of high quality.
3. Mission 3 – enhance capabilities, skills and awareness: to achieve its vision the Geospatial Commission must develop more people with the right skills and tools to work with location data, across organisations and sectors, to meet the UK's future needs and support global development.
4. Mission 4 – enable innovation: the Geospatial Commission will maximise the commercial opportunities for innovation and promote market-wide adoption of high-value emerging location technologies.

Further detail is available in the UK Geospatial Strategy document available here.

Partner bodies

In providing oversight of the UK's geospatial ecosystem, the Geospatial Commission has a close relationship with six "partner bodies" (the Geo-6). A significant amount of the UK's location data framework exists within the Geo-6. In addition, the Geospatial Commission engages with a wider range of public sector bodies who play important roles in the geospatial ecosystem.

Figure 4 Geospatial Commission partner bodies (the Geo-6)

Source: *Geospatial Commission (2020)*

Note: *The partner bodies are The British Geological Survey, The Coal Authority, HM Land Registry, Ordnance Survey, UK Hydrographic Office and The Valuation Office Agency.*

These partner bodies have diverse functions and organisational statuses. This partnership model enables crucial cross-government collaboration and expertise-sharing that will help to ensure alignment with the UK's Geospatial Strategy and that the whole of the UK's geospatial data ecosystem remains greater than the sum of its parts.

1.4 Using economic frameworks and evidence to identify policy opportunities

The Geospatial Commission intends to create an evidenced view of the policy actions that will support positive outcomes in the location data market for current and future users. This targeted policy support will be appropriate in instances where there is evidence that it would benefit market outcomes.

This piece of work uncovers insights relating to the economic structure and functioning of the geospatial market. These economic concepts can link directly to rationales for government intervention and can therefore be used by the Geospatial Commission to highlight policy opportunities. Relevant economic concepts in this context include:

- **Externalities and spillovers:** the benefits of geospatial data production to an individual firm, or the benefits of geospatial data consumption to an individual user, may not include all benefits to society. Government intervention may therefore be justified to increase the production or consumption of geospatial data products or services in order to increase societal welfare.
- **Information issues:** users may struggle to differentiate between low- and high-quality geospatial offerings. This could reduce demand and limit the incentives of suppliers to improve the quality of their offerings. To address this issue, government intervention could be justified to provide independent information on geospatial offerings and their associated use cases.
- **Market power and contestability:** in some markets, certain suppliers may be able to maintain a strong market position and a high market share, which limits

the choice of end users. In some of these cases, government intervention could be required to reduce barriers to entry and create a more level playing field.

It is important to note that poorly targeted policies could reduce, rather than enhance, market effectiveness, which emphasises the importance of collecting evidence via a variety of mechanisms, including this study, prior to intervening.

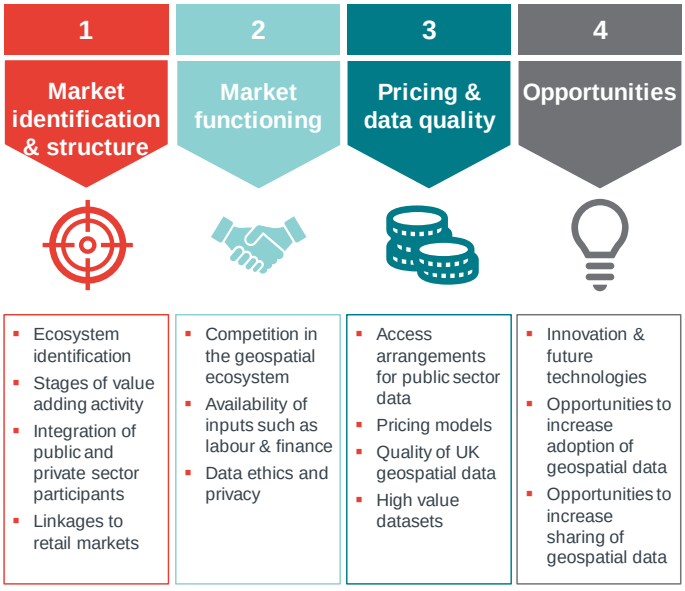
It should also be noted that this study into the geospatial data market is not a study of formal competition or market concentration. Measuring concentration and competition requires detailed agreement on what company activity is in or out of scope of the agreed market definition, which is an extensive process within competition casework. However, our assessment of the prevailing economic characteristics in the provision of geospatial data and services provides a useful observation for the development of policy recommendations that can support the market.

1.5 Terms of reference

The Geospatial Commission has asked us to explore the size, features and characteristics of the geospatial data ecosystem. Our study provides insights into the participants of the geospatial data ecosystem and market dynamics. Findings from our study highlight existing frictions and market dynamics as well as opportunities for the Geospatial Commission to improve market functioning. The Geospatial Commission is interested in addressing a number of research questions which fit into four themes, as we set out below (Figure 5).

Research themes 1-3 provide valuable insights and are interesting to explore in their own right. In addition, they are partially a means to an end, as they help to inform our understanding of future opportunities in this context.

Figure 5 Research themes



Source: Geospatial Commission

Findings from this report inform the Geospatial Commission about the greatest opportunities for improving the functioning of the market. Understanding how the geospatial data ecosystem operates is central to ensuring that any possible policy recommendation is as effective as possible. It is not within the scope of the work to make specific policy recommendations to the Geospatial Commission.

Therefore, our work forms part of the evidence base that the Geospatial Commission is developing to guide future policy actions. The economic framework we have developed and the insights we have gained from our quantitative and qualitative analysis allow us to explore the size, structure and functioning of the market. This in turn allows the Geospatial Commission to focus on the future opportunities that will improve the functioning of the geospatial data ecosystem.

Prior to carrying out this work, we did not make any assumptions about the existence of market frictions or failures, but we did consider previous work, particularly that relating to the Geospatial Commission's call to the sector for evidence in 2018.[27] In its Annual Plan 2019-2020, the Geospatial Commission subsequently summarised the key themes which emerged from the hundreds of responses they received:[28]

- Almost all responses highlighted that geospatial data is often of varying quality, and data access was viewed as a challenge in some cases.
- Many responses also cited an apparent skills gap in the sector.
- Many responses also noted that the Geospatial Commission may have a role to play in fostering geospatial innovation.

We carried out our work and collected evidence with these themes and issues in mind.

1.6 Structure of the report

The remainder of this report is structured as follows:

- In Section 2 we outline our methodological approach for this piece of work.
- In Section 3 we present the quantitative results of our market identification and sizing work.
- In Section 4 we examine the structure of the geospatial data market and its characteristics as an ecosystem.
- In Section 5 we explore how the geospatial data market functions and its economic dynamics.
- In Section 6 we explore in detail three specific markets segments which include geospatial data use cases.
- Section 7 contains our bibliography and is followed by technical annexes on our methodologies.

[27] Geospatial Commission (2019 A) https://www.gov.uk/government/publications/geospatial-commission-call-for-evidence-responses

[28] Geospatial Commission (2019 B) https://www.gov.uk/government/publications/geospatial-commission-annual-plan-2019-2020

2 APPROACH AND METHODOLOGY

This report is the culmination of a detailed and multi-faceted study over the course of nine months, during which we worked closely with the Geospatial Commission's analysis team and officials across their policy and project functions. We used a rich variety of tools throughout the study including:

- a review of existing literature;
- development of a bespoke economic framework;
- a series of over 40 interviews with the Geospatial Commission's partner bodies, devolved administrations and private sector stakeholders active in the geospatial ecosystem;
- a roundtable discussion with techUK members;[29] and
- a detailed data mapping and triangulation exercise to facilitate our market identification and sizing exercise, combining data from multiple sources.

In addition to the findings in this report, the methodology itself is a critical output for the Geospatial Commission. We designed both the quantitative and qualitative approaches to maximise replicability. This is particularly important given the evolving nature of the geospatial data ecosystem, which implies that this type of study may need to be repeated in the future.

This section summarises our quantitative and qualitative methods. We provide more details in the technical annexes.

2.1 Uncovering the scale and nature of the geospatial data market

2.1.1 Overview of approach

Introduction and objectives

One of the key priorities for this study was understanding which firms are active in the geospatial data market in the UK. Identifying these actors, exploring the scale of their current operations and understanding what activities they are carrying out across the economy helped us to identify and define the UK's geospatial data market.

Given the diverse range of use cases for geospatial data which are spread across the economy, it was decided (in alignment with previous conclusions made by the Geospatial Commission's analysts) that existing classification systems such as the Office for National Statistics' (ONS) Standard Industrial Classification (SIC)[30] codes did not accurately capture a high proportion of relevant geospatial activity. We therefore needed to create our own definition based on a granular review of actual individual firm-level activities.

[29] https://www.techuk.org/events/roundtable/item/16569-techuk-geospatial-data-market-roundtable-event

[30] https://onsdigital.github.io/dp-classification-tools/standard-industrial-classification/ONS_SIC_hierarchy_view.html

We did not seek to replicate existing research which attempted to place a potential economic value on better use of geospatial data as a whole.[31] Rather, our market identification work allowed us to highlight a comprehensive range of organisations for whom geospatial data forms a key part of their commercial activity: we define these companies as "core" geospatial companies. This includes firms which may not conventionally consider themselves part of the geospatial data market. However, this excludes firms which manufacture hardware and technology that can be used to capture geospatial data but whose primary purpose is for other uses.[32] It also excludes companies for which geospatial data is an input, but not a core input, and companies for which location functionality is a non-essential feature of their product. The use cases of geospatial data are explored in our qualitative engagement.

We recognise that this definition of "core" geospatial companies does not include companies that are part of the wider geospatial ecosystem. For clarity, this report is not suggesting that these wider companies do not collect or use any geospatial data, rather, that geospatial activity is not a major part of their offering. The companies we identified illustrate how geospatial data is a crucial component of a diverse range of sectors. Our work also highlights emerging trends in terms of new use cases and technological innovations.

While we were as comprehensive as possible in carrying out this part of the work, the diverse range of firms and fast-moving nature of geospatial data uses meant it was not possible to identify every single relevant organisation across the UK. This serves to highlight the importance of using a replicable and transparent methodology which can be deployed by the Geospatial Commission in the future. Subsequent reruns of this market-sizing work will allow the Geospatial Commission to measure the growth in the number of geospatial companies and changes in their size.

Building on the Geospatial Commission's previous market identification exercise

Our methodology was developed and implemented in conjunction with the Geospatial Commission's analysis team to ensure that we built on their approach and incorporated learnings from their previous internal research on geospatial market sizing.

In 2019 the Geospatial Commission identified small and emerging companies active in the geospatial data ecosystem. These included companies whose primary business offer was informed by geospatial data and excluded hardware producers or firms for which geospatial data is used only for internal decision making.[33]

The Geospatial Commission identified companies by devising a list of search terms which related to geospatial activities (described in greater detail below) and matching these terms against company descriptions contained in a database of

[31] In particular, "An Initial Analysis of the Potential Geospatial Economic Opportunity" (Cabinet Office, 2018)

[32] For instance, drone manufacturers are not captured where the primary use is for leisure activities or media activities like aerial wedding photos.

[33] Real estate and oil exploration companies were also excluded.

high-growth firms.[34] The results were then manually reviewed to ensure they fit the above criteria.

Below we describe the method that we used in conjunction with the Geospatial Commission for this updated market-sizing and identification exercise. This includes a more in-depth identification procedure and incorporates a wider variety of input data sources.

Summary of approach

We used two methods to identify core geospatial companies. To be included as a core company, geospatial data has to be a key part of their commercial activity, as without geospatial data the company could not provide its goods or services.

1. We used **search terms and rules** based on **company descriptions**. This was our primary method and created the main dataset of companies.
2. We reviewed and incorporated selected firms that were identified by **previous research**, the Geospatial Commission's own sector expertise or our qualitative engagement.

The second method allowed us to create an additional list of relevant companies, which we used to validate and refine our search term identification process.

2.1.2 Identifying firms through company definitions

Search terms used

In line with the Geospatial Commission's previous work, as well as other reports such as Nesta's (2018) "Flying High" report on drones,[35] our primary method of identification involved flagging companies based on the content of their company descriptions. These descriptions either came from centralised databases which track commercial activity or the companies' own websites. The aim was to identify companies for which geospatial data is a core part of their offering, i.e. those companies which could not deliver their product or service without geospatial data.

This means that we did not identify large companies which use geospatial data for some of their products and services but do not refer to these geospatial activities in their description. By and large, the Geospatial Commission is already aware of these organisations due to their significant market presence. We discuss how we collated firms that we identified through other research and engagement in Section 2.1.3.

We started with the list of search terms previously used by the Geospatial Commission in its earlier market-sizing exercise. This list consisted of around 50 key words and phrases which were identified by the Geospatial Commission through desk-based research and sector expertise. These terms were diverse in nature and covered different:

- types of data capture, e.g. earth observation, drone, satellite;
- forms of activity, e.g. oil exploration, route optimisation;

[34] Beauhurst https://about.beauhurst.com/. See below for further detail.

[35] https://media.nesta.org.uk/documents/Flying-High-full-report-and-appendices.pdf

- types of analysis, e.g. topographical, hydrographic;
- types of data, e.g. address, visualisation; and
- economic sectors, e.g. marine, maritime.

We reviewed that list and explored which search terms were most successful in identifying relevant firms and which ones led to significant numbers of false positive results. This resulted in us dropping a limited number of generic search terms.[36] We also added a considerable number of new search terms to the list based on our review of relevant literature. This review included:

- Policy reports, e.g. "The Future Technology Review" (Public, 2019);[37] "Flying High" (Nesta, 2018);[38]
- Academic reports, e.g. "Digital Economics" (Goldfarb and Tucker, 2019);[39] CRCSI "Global Outlook Report" (Coppa, Woodgate and Mohamed-Ghouse, 2018);[40] and
- Industry reports, e.g. "GeoBuiz" (GeoBuiz, 2019).[41]

We also engaged further with a wide team of Commission colleagues to ensure the list of search terms was comprehensive. This led to us identifying new search terms covering other data capture methods (e.g. lidar), activities (e.g. environmental mapping), data types (e.g. 3D mapping) and sectors (e.g. precision agriculture). We also included more specific software search terms and companies such as hexagon and Geowise.

We further expanded the list throughout our work via a dynamic process of reviewing descriptions of identified companies. This allowed us to determine whether we were missing any potentially relevant terms or whether we could create a more precise search term. For example, we amended "geophysical" to the phrase "geophysical survey" after reviewing company descriptions to avoid identifying companies that were not relevant.

Tiering of search terms

It became apparent that the presence of certain search terms within a company description almost always indicated that the firm was in scope of our research, while other search terms tended to flag many non-geospatial firms as well as a small number of geospatial firms. We therefore implemented a system of rules using tiers to increase precision and limit the amount of manual input and ad-hoc decision making required:

- Tier 1 rule: Any company description that had *geospatial* (or any variants for spelling this) was always included.
- Tier 2 rule: Companies were included if they were classified as operating in specific sectors judged to involve geospatial activity and had descriptions that included specific geospatial search terms. For example, if the company

[36] For example, we dropped *data* as a search term. This was identifying a vast number of firms that use data in some form but not specifically identifying firms that use geospatial data.

[37] https://www.gov.uk/government/publications/future-technologies-review

[38] https://media.nesta.org.uk/documents/Flying-High-full-report-and-appendices.pdf

[39] https://www.aeaweb.org/articles?id=10.1257/jel.20171452

[40] https://www.crcsi.com.au/assets/Resources/CRCSI-Global-Outlook-Report-2018.pdf

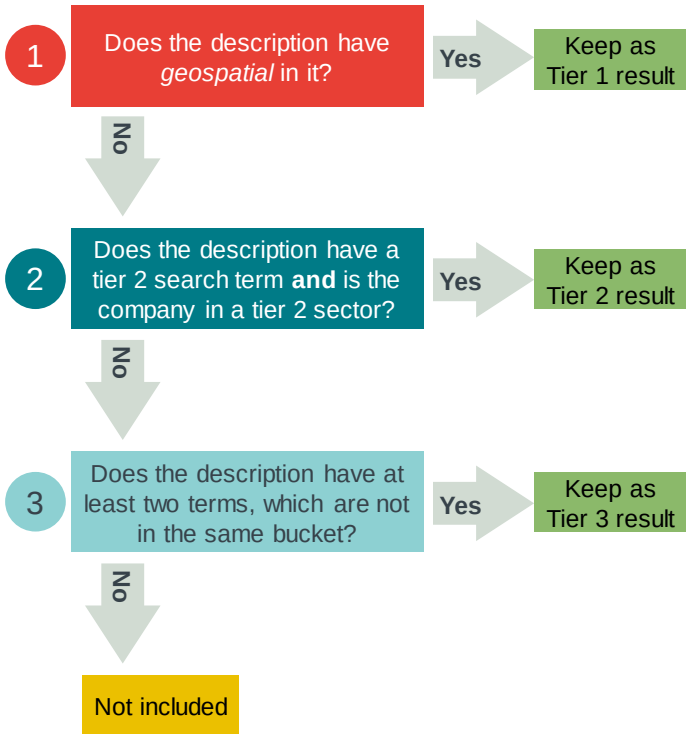
[41] https://issuu.com/geospatialworld/docs/20190329-geobuiz-report-2019-freeve

operated in the property and land sector and its company description contained search terms such as aerial survey, autonomous vehicle and cadastral, then it was counted as a Tier 2 geospatial company.

- Tier 3 rule: Regardless of the sector in which they operate, if a company description contained at least two search terms that were Tier 3 terms, then it was identified as a relevant company. These Tier 3 terms are more generic than the Tier 2 list and include terms like 3D visualisation and drones. Multiple relevant terms were therefore needed within a company's description before it was included. Some terms are very similar to each other and therefore we used groupings so that the second term could not be from the same grouping (we term them "buckets" in Figure 6 below). For instance, map, map data, mapping data and mapping software are considered as one group.

The process of applying the tiers is set out in the figure below. A company is not more important or "more geospatial" because it is found in Tier 1. The tier numbers reflect the rules in the data collection process rather than any kind of ranking system.

Figure 6 Tiered system



Source: *Frontier*

Note: *There are specific inclusion and exclusion rules for certain terms and sectors applied around this framework.*

As part of the iterative review process and then during the validation phase, we set specific inclusion and exclusion rules for companies provisionally identified through the search terms. These rules provide narrower criteria to further reduce the number of false positives. This extra layer of granularity was necessary because we identified companies across many different sectors and with many different use cases for geospatial data. Therefore, it was not possible to rely on broad-brush rules that would always identify only the relevant companies. Some rules were

applied to all sectors, such as excluding companies that used "professional society" or "training" anywhere in the description. Other rules were specific to certain sectors or search terms. For example, a company with "radar" was excluded when "manufacture" was also in the description, and "map" was excluded when the company was in the automotive sector. We also used a slightly different set of rules for companies identified through projects receiving grant funding through UK Research and Innovation (UKRI) to reflect that this dataset does not have sectors and cannot be searched using compound search terms.

In total, our final list consisted of 99 Tier 2 search terms and 157 Tier 3 search terms.

Datasets used

There is no single dataset that contains every potentially relevant company and all metrics of interest. Therefore, we rely on coverage across a number of platforms and datasets to ensure that the results are representative and robust.

The Geospatial Commission previously used the Beauhurst[42] platform to identify and understand the size of the market by examining patterns of equity funding raised. Beauhurst tracks and provides information on companies, particularly those which are small and high growth, with eight specific criteria.[43] It is especially useful for providing equity data not available on all other platforms and for understanding the small and start-up segments of the market.

For this work, we also wanted to include both larger companies and smaller companies which may not match Beauhurst's tracking criteria, as well as any companies which received funding for geospatial R&D activity. Glass.ai[44] provides an AI algorithm that reads the web using proprietary language that understands technology to provide a bespoke dataset of UK companies and associated descriptions. Bloomberg[45] provides financial data only for publicly listed companies. The UKRI[46] database provides information on projects that have received grant funding, including whether this was for areas such as research or R&D.

The four datasets that we chose collectively provide a comprehensive overview of the market as each dataset covers a slightly different part of the ecosystem. For instance, Beauhurst includes small but growing companies that will not be on Bloomberg and may not have received grant funding tracked by UKRI, whereas glass.ai can identify a company that does not meet Beauhurst's tracking criteria and is not publicly listed and therefore not identified by Bloomberg. The datasets also use different methods to generate the company description that is searched for the key words and phrases:

- Beauhurst provides a company description in the company's own words as well as the platform's description;

[42] https://platform.beauhurst.com/

[43] More information on Beauhurst's tracking criteria available in Annex B.6 and here: https://platform.beauhurst.com/help/faq#the-venture-debt-trigger .

[44] https://www.glass.ai/

[45] https://www.bloomberg.com/europe

[46] https://gtr.ukri.org/?_ga=2.124629448.315603098.1597241193-1576263268.1571029750

- glass.ai finds the description provided by companies in their own words on the website;
- Bloomberg provides its own description of the company; and
- UKRI uses project descriptions that are submitted by the grant applicants.

Figure 7 Datasets used for identification

Data source	Summary	Application
glass.ai	▪ Reads company websites for key words and uses AI to map out sectors	▪ Identifies specific companies **of all sizes** who refer to geospatial terms on their website
Beauhurst	▪ Database of high growth firms defined according to eight criteria (e.g. secured equity investment)	▪ **Identifies emerging firms** on the supply-side of the markets using specific search terms to identify whether their primary business proposition is geospatial related
Bloomberg	▪ Financial information relating to publicly listed companies.	▪ Identifies specific **publicly listed** companies.
UK Research and Innovation	▪ Database of all grants given by Innovate UK (IUK) covering 2004-19. IUK offers funding of between £25,000 and £10 million for innovation projects led by UK-based businesses.	▪ Identifies which firms are **receiving funding** to carry out geospatial R&D.

Source: Frontier

We present our list of included datasets in Figure 7 above.

The process for matching specific companies between multiple datasets is important to avoid duplications which would artificially over-estimate the size of the market. We present further detail on this matching process in Annex B.5.

The identification datasets we listed above do contain metrics which indicate the size of the companies identified. These include the number of employees, equity funding raised, as well as firms' location and sector. We include additional metrics from the FAME dataset which has more information on business metrics such as turnover and employment. The FAME dataset is published by Bureau van Dijk,[47] which uses original account filings and documents filed at Companies House for financial metrics. The dataset also includes SIC codes and industry descriptions.

The datasets cover slightly different time periods and have varying coverage of certain sizing metrics:

- Beauhurst data provides limited historical financial data but the extractions can be used to track changes over time if repeated. The data is updated with annual reports but also whenever there is a new equity raising or valuation relating to an included company. Where the data has been made public, it includes turnover, equity funding and the number of employees. **Throughout the period of March - August 2020, we extracted historical data on our geospatial companies**

[47] https://www.bvdinfo.com/en-gb/

- Bloomberg data has the most recent capitalisation, turnover in the past 12 months and revenue growth over the past 12 months.[48] The data can be updated monthly but not all companies are updated with the same frequency and there are some gaps in the data. It does not include the number of employees. **Throughout the period of March-August 2020, we extracted historical data on our geospatial companies**
- FAME data covers 2009-2019. Our extract consists of a static snapshot of the database as at August 2020, but FAME updates its platform as new information is published.
- Glass.ai provided us with the most recent revenue and employee numbers that it was able to read from online sources. Our bespoke dataset does not include equity funding. Glass.ai compiled our dataset in June 2020.
- UKRI is slightly different as the grants are one-off amounts. The data goes back to 2005 with start and end dates for the projects. The data is updated whenever a new grant is awarded. Grant sizes are captured but no associated data for the recipient company, such as revenue or number of employees, is captured. We extracted data for **Throughout the period of March-August 2020, we extracted historical data on our geospatial companies**

Validation

There were two main aspects to validating our market identification process and the firms it highlighted:

1. The first was to confirm that we had identified appropriate firms: each firm included in our market identification should be an organisation for which geospatial data is a core part of their offering. To confirm this was the case, we carried out quality assurance, which enabled us to be confident that the search terms and tiered rules were working accurately.

   This validation was implemented on an ongoing basis by reviewing preliminary results with the Geospatial Commission and making refinements to the search terms and exclusion rules. For instance, through iterations with glass.ai we changed the threshold of search term matches within Tier 3 to be at least two terms rather than at least three, which we had initially thought appeared appropriate.

   At the conclusion of our market-sizing work we also carried out a dedicated validation process via random sampling of the results. Full details of the process are in Annex B and we set out a visual summary in Figure 8 below. In conjunction with the Geospatial Commission, we manually reviewed a 10% sample of companies which were identified in Tiers 1, 2 and 3. We then repeated these checks to make sure that our tiering rules had not excluded any relevant companies. The final step was an additional check to ensure companies with high turnover (those which would have a material impact on the sizing results) were correctly identified.

[48] Additional financial metrics are available on the platform

Where the validation review led to changes in search terms and rules, we conducted final random sampling of these changes to ensure the rules were robust.

Figure 8 Random sampling approach to identifying core geospatial companies

Source: Frontier

2. The second aspect was to check that the search terms and rules effectively picked up the companies that we already knew existed and had geospatial data as a core part of their offering. Our second identification method, which we describe below (reviewing other research and firms found through qualitative engagement), was used during this stage to check if known geospatial companies were also present in our master list of firms identified via search terms.

2.1.3 Identifying firms through the literature review, engagement with the Geospatial Commission and qualitative research

As we noted earlier, research into the providers and users of geospatial data already exists. We reviewed existing work to avoid duplicating efforts and to benefit from and build on existing insights. We identified relevant sources through our literature review, engagement with the Geospatial Commission and our qualitative engagement.

Sources for this additional information on geospatial providers and users included resellers/intermediaries of selected Geospatial Commission partner bodies, and market reports such as the GeoBuiz (2019) "Geospatial Industry Outlook". The full list of sources is in Annex B.5.

Whether companies are defined as core geospatial companies depends on how geospatial activity is defined and what identification process has been used in the previous studies. This varies across different studies in line with their respective aims. Therefore, not all companies from other research reports are relevant for our analysis. In discussion with the Geospatial Commission, we identified the "Future Technologies Review" (Public, 2019) and Nesta's (2018) "Flying High" drones report as the most relevant. We added the majority of these companies to our list of core geospatial companies if they were not already included.[49] We also studied closely the lists of commercial intermediaries and resellers provided to us by partner bodies.

[49] A few companies were excluded during a manual review as they were identified as not being relevant.

The remaining companies were consolidated as an additional list of companies in the wider geospatial ecosystem, which will help the Geospatial Commission in future work. Reviewing these companies in detail is outside the scope of this report.

2.2 Qualitative engagement to answer about the dynamics of the market

2.2.1 Overview of approach

Introduction and objectives

As we set out in Section 1.5, the Geospatial Commission defined a number of research priorities for our work, which covered:

- market identification and structure;
- market functioning;
- pricing and data quality; and
- future opportunities.

Our quantitative market-sizing and identification analysis can help us to understand the scope and size of the geospatial data market, including how it can be better characterised as an ecosystem. We tackled the remaining research questions via a programme of qualitative research, which we describe in detail below.

Summary of approach

Our qualitative research was guided by a bespoke economic framework created for this study and a set of hypotheses we wanted to test through this engagement. The economic framework was developed as a tool to help us address the Geospatial Commission's research priorities.

Prior to any qualitative engagement, we jointly worked with the Geospatial Commission to articulate the areas we wanted this part of our work to inform. To ensure that no topic was omitted, we broke down the four research priorities into specific hypotheses of interest which we could put forward to stakeholders. We also used our economic framework to inform us about which stakeholders were likely to provide the most helpful insights in each area of interest.

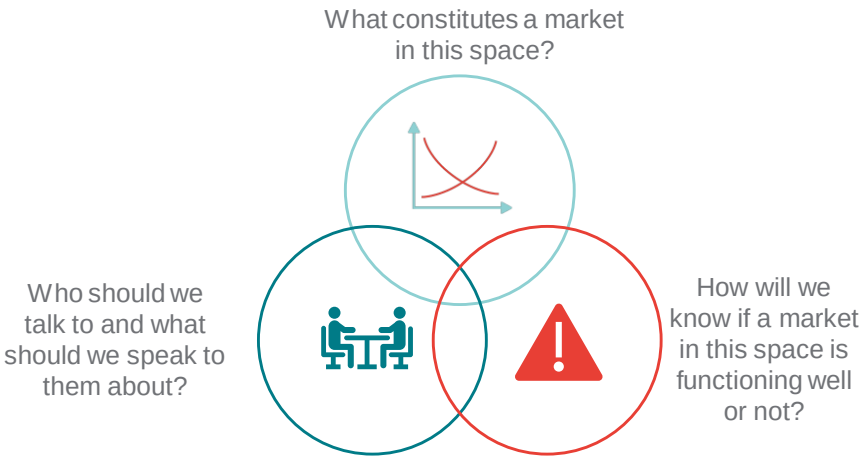
We wanted to cover the entire geospatial data market encompassing a range of sectors and activities from data collection to demand for final products and services. We also carried out three detailed case studies within this qualitative engagement. This allowed us to explore the functioning of three topical areas in depth. Some of the hypotheses of interest are centred around and specific to the three case studies. These case studies were chosen in conjunction with the Geospatial Commission to focus on areas that are relevant for the Commission's strategy and where there is insufficient existing evidence to draw conclusions on market functioning.

Throughout the qualitative engagement process, we used interim findings to inform the questions we asked subsequent stakeholders. This agile approach meant that we could probe into areas most relevant to the Geospatial Commission's priority areas as well as ensuring that we minimised the risk of gaps in the evidence base.

2.2.2 Economic framework

We developed an economic framework during the first phase of the project which we subsequently refined following engagement with the Geospatial Commission. The economic framework guided our work and allowed us to illustrate the different types of participants in a geospatial data market. It also enables us to apply economic concepts to the geospatial data market. We can use our economic framework to inform our conclusions regarding market functioning which arise from our qualitative engagement. Finally, it ensures that we ask the right questions of the right organisations during our qualitative engagement to understand the market structure and functioning. We summarise the reasons for creating an economic framework in Figure 9 below.

Figure 9 The questions the economic framework helps to answer



Source: Frontier

Our economic framework links closely to our market identification and sizing analysis as it allows us to determine how the companies identified fit into and function as part of the whole geospatial data ecosystem.

Sources of evidence used to build the framework

To develop our economic framework, we built on existing work carried out in the context of geospatial data and the digital economy more widely, and drew on economic theory. We incorporated a range of evidence from multiple sources:

- Literature review covering a range of existing work both in the UK and internationally. For example:
  - Literature on the role of the Geospatial Commission and similar bodies in other countries to fully understand the relevant context (e.g. "Geospatial Commission Annual Plan 2019-2020" (Geospatial Commission, 2019 B))[50];

[50] https://www.gov.uk/government/publications/geospatial-commission-annual-plan-2019-2020

  - Literature on value chains in general and their application to geospatial data, in particular (e.g. “Big Data in Earth Observation” (European Commission, 2017))[51];
  - Existing research on the geospatial market (e.g. “Initial Analysis of the Potential Geospatial Economic Opportunity” (Cabinet Office, 2018)[52] and “The UK’s Geospatial Data Infrastructure: Challenges and Opportunities” (ODI, 2018)[53];
  - The value of data and digital economies (e.g. “The Economic Value of Data: Discussion Paper” (HM Treasury, 2018 B))[54];
  - Wider literature on data usage (e.g. “Challenges in Using Data Across Government” (National Audit Office, 2019))[55]; and
  - Deep dives into industries which use geospatial data (e.g. “Size & Health of the UK Space Industry” (London Economics, 2019))[56].
- Engagement with experts from the wider Commission team and through roundtables and interviews.
- Co-development with the Geospatial Commission team on an iterative and ongoing basis.
- Our experience of exploring the competitive structure and features of other markets.

Content of the framework

Our economic framework allows us to visually illustrate the geospatial data market. Conventional economic market studies would broadly segment a market into a “demand” and a “supply” side. We found that the geospatial data world is best described as an ecosystem: a series of interconnected markets. However, it is still helpful to define the boundary of our ecosystem at a high level. We include a broad distinction between “supply” of geospatial data and “demand” within any specific geospatial market. We illustrate this in Section 4.

We also use our economic framework to illustrate the stages involved in generating value from geospatial data from the collection of data all the way through to the use of geospatially informed products and services.

2.2.3 Qualitative evidence gathering

Before we engaged with participants in the geospatial data ecosystem, we grouped them into four main groups, led by our economic framework. This allowed us to target which hypotheses to test with the right group.

51 https://ec.europa.eu/growth/tools-databases/dem/monitor/sites/default/files/DTM_Big%20Data%20in%20Earth%20Observation%20v1.pdf

52 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/733864/Initial_Analysis_of_the_Potential_Geospatial_Economic_Opportunity.pdf

53 https://theodi.org/article/geospatial-data-infrastructure-report/

54 https://www.gov.uk/government/publications/the-economic-value-of-data-discussion-paper

55 https://www.nao.org.uk/report/challenges-in-using-data-across-government/

56 https://www.gov.uk/government/publications/uk-space-industry-size-and-health-report-2018

We engaged with the participants through two methods: semi-structured interviews and industry events/roundtables.

Stakeholder groups

We identified four main stakeholder groups, each of which represented different actors in the geospatial ecosystem who we wanted to engage with. Using our economic framework, we divided the ecosystem into:

- **Partner bodies and devolved administrations** which play a crucial role across the entire geospatial ecosystem. As we describe above, the Geospatial Commission has a unique relationship with six "partner bodies" (the Geo-6). We therefore wanted to engage with this group as a significant amount of the UK's location data framework exists within the Geo-6. We wanted to ensure that evidence was representative of public sector activity across the UK, so we spoke to organisations active within devolved administrations. We recognise that geospatial activity is also undertaken by other public sector bodies such as the Met Office and a range of central government departments.
- Commercial organisations active in the **creation and supply** of geospatial data. These private sector firms are actors whose core focus is the production and analysis of geospatial data and provision of services informed or underpinned by geospatial data. These firms are best placed to provide insight into the current functioning of the market, geospatial business models and evolution in the take-up of their products and services. Some of these firms are small and rapidly growing whereas others are large and more established.
- Commercial organisations which are primarily **users of geospatial data**. These private sector firms demand geospatial data products and services to improve their own product range or inform decision making. Importantly, their customer base is likely to consist of individuals who are final users of goods and services underpinned by geospatial data. They can provide us with insights on the quality of current offerings in the market and potential barriers to future adoption across the economy.
- Facilitators who enable **effective functioning of the geospatial data ecosystem**. This group includes funders of geospatial firms, innovation hubs and accelerators. These organisations provide unique perspectives on the health of the overall ecosystem, key opportunities and challenges.

By engaging with each of these groups, we gathered a diverse range of views and insights from numerous different perspectives.

Semi-structured interviews

The bulk of our qualitative engagement consisted of semi-structured interviews. In advance of each interview, we developed a topic guide which was structured in line with the areas of interest that we agreed with the Geospatial Commission. We tailored each topic guide to the interviewee's activities and role in the geospatial ecosystem. We then used the topic guides to structure our conversations while also flexibly allowing interviewees to provide input on other areas of perceived importance. These topic guides were shared with participants in advance. We provide an illustrative topic guide in Annex A.1.

The semi-structured interviews were carried out on an individual basis with each organisation, although in many cases multiple people who filled different roles in the same organisation attended the same interview. This meant that participants could speak as freely as possible. The majority of interviews were held over the phone or via video conference.

In total, we carried out 42 semi-structured interviews. This allowed us to engage with a considerable number of organisations fulfilling different roles across the UK's geospatial ecosystem. Therefore, while our qualitative engagement cannot be thought of as representative of the entire geospatial ecosystem, it does provide a robust source of evidence for the Geospatial Commission.

We jointly selected organisations to interview with the Geospatial Commission. Firstly, we agreed to engage with each of the Geo-6 organisations as well as two organisations representing devolved administrations in Northern Ireland (Ordnance Survey Northern Ireland) and Scotland (Registers of Scotland). This accounted for eight of our interview slots. For the remaining 34 slots, we identified organisations via three main routes:

- existing Geospatial Commission relationships from prior engagement;
- existing Frontier linkages from carrying out related work; and
- firms we had identified via our market-sizing work and subsequently contacted.

We had a number of criteria in mind when selecting our sample frame:

1. We wanted to cover numerous Geospatial Commission interest areas which were informed by previous research such as the Digital Land Review. This included areas such as consumer services, transport and proptech.
2. The Geospatial Commission was also interested in obtaining an in-depth understanding of specific value chains as part of this piece of work. This led to us defining three case study areas where we consciously over-sampled so as to provide a greater level of detail. These cases studies covered:
    a. Use of **mobile phone network data** to capture aggregated patterns of individuals' movements. Information derived from mobile networks and related sources are an increasingly important form of geospatial data. They may play a significant role in a number of sectors going forward. However, all the potential use cases are not currently well understood. The benefits of better understanding people's movements are potentially large and could create new insights or generate efficiencies.
    b. **Automated mobility** will be of huge value to the economy and could transform large parts of society. There is also a clear international opportunity for any country that can develop an effective ecosystem template in terms of data, standards and policy. Geospatial data has an important role to play in driving this new form of technology.
    c. The **insurance sector** has previously been identified as a key future consumer of geospatial data. Geospatial data is currently being used in this context, but adoption is not universal. The underlying geospatial market segment is changing and may be experiencing an increase in contestability, which is worth exploring further.

3. We also wanted to ensure that we engaged with firms at multiple different stages of the value chain. We wanted to incorporate the insights from firms which are involved across data collection and acquisition as well as firms which are focused more on the usage of cleaned and processed geospatial data.

While the majority of firms we contacted were happy to take part, some organisations either did not respond or decided to opt out. In total, we invited approximately 50 firms to take part in an interview and we ended up engaging with 42 of these.

Industry roundtable

We also gathered qualitative insights from a sectoral event hosted by techUK[57] and the Geospatial Commission. All techUK's members were invited to attend a Geospatial Data Market Roundtable and provide input on a number of topics such as the evolution of demand for geospatial products and services and potential barriers to innovation.

2.2.4 Synthesis of findings

We present the key results from all of our qualitative engagement in Section 5. To pull out overarching themes, we followed a four-step approach:

- We firstly took detailed notes during each interview.
- Next, we aggregated individual interview notes into consolidated write-ups covering similar types of stakeholders who were asked related questions. These groupings were based on stakeholder type or interviewee sectoral focus. We organised these write-ups thematically.
- We then used these aggregated write-ups to highlight areas of consensus and disagreement amongst different interviewees on the same high-level topic.
- Finally, we summarised across all qualitative write-ups and pulled out key insights according to the Geospatial Commission's research themes of interest. Multiple Frontier personnel were involved in this process to ensure that the findings were robust and quality assured.

2.2.5 Data protection

Frontier's information security policies are intended to robustly protect our data assets and personnel to meet our clients' requirements, comply with the Data Protection Act, appropriate legislation and recognised industry best practice.[58]

When carrying out this piece of primary research we drew up a Privacy Statement which we sent to all interviewees. This set out the type of information we would collect and what we planned to do with it, along with their rights as a data subject.

In order to facilitate open and candid conversations with interviewees, we gave assurances that no specific findings would be linked to any single organisation that we spoke to. The results we present in this report reflect that. In order to further

[57] techUK is the UK's leading technology membership organisation, with more than 850 members spread across the UK. https://www.techuk.org/about

[58] https://www.frontier-economics.com/uk/en/legals/

protect anonymity, we do not include in this report the list of specific private organisations which we spoke to.

3 MARKET IDENTIFICATION AND SIZING

In this section we review the findings from the market identification and sizing exercise. We focus on the companies found through the search term and tiered rules methodology as well as relevant organisations identified by Nesta's (2018) "Flying High" drones report[59] and the Geospatial Commission's (2019 C) "Future Technologies Review".[60]

The market-sizing statistics presented in this section refer to those firms where up-to-date revenue and number of employee figures were available.

NUMBER OF FIRMS IDENTIFIED AS CORE SUPPLIERS OF GEOSPATIAL DATA

The search terms and tiered rules identified almost 2,000 companies for which the supply of geospatial data is a core activity. We also identified approximately 500 R&D and innovation projects which received grant funding from UKRI since 2005 and had a core geospatial focus.

Total turnover was £6 billion in 2018 amongst companies where data was available (this accounted for 30% of our sample). This is a highly conservative estimate as it does not include turnover data for large companies for which geospatial data accounts for a share of their activity, but for which other parts of the organisation do not rely on geospatial data. It is difficult to attribute a portion of their turnover data to geospatial activities, so we excluded them.

SMEs identified in the Beauhurst data raised over £1 billion in fundraising and received over £150 million in grants over the period 2005-2019. Relevant geospatial projects received grants through UKRI worth over £260 million over the same timeframe since 2005.

Employment data was available for two-thirds of the firms we identified. We found that this subsample of geospatial organisations employed over 115,000 people by headcount in 2019.

Geospatial firms are most commonly found in technology, professional services, engineering and mineral/fossil fuel exploration sectors. Geographically, companies were most common around London and the South East, although all regions of the UK were represented. Specifically, we found emerging clusters of activity in Edinburgh, Cambridge and Belfast.

3.1 It is difficult to identify core geospatial companies

Even with a focus on an ecosystem rather than a traditional market structure, it is difficult to have clearly define what should be included in the "core" set of geospatial companies. Our definition of "core" companies is limited to ***organisations which could not deliver their product or service without geospatial data***.

[59] https://www.nesta.org.uk/report/flying-high-challenge-future-of-drone-technology-in-uk-cities/

[60] https://www.gov.uk/government/publications/future-technologies-review

Deciding on an appropriate market definition and determining what activities are included or excluded are very important in competition economics and regulatory cases. This usually involves "serious consideration" and requires detailed investigation (Digital Competition Expert Panel, 2019).[61] Our study did not involve an empirical market definition exercise using competition economics. However, our chosen definition does have implications for our estimates of market size.

We were not able to use specific sectors to identify companies. This is because we found relevant companies across many sectors and any sector that included relevant companies would also always include companies that were not relevant. This permeation of geospatial data across the economy made it harder to identify and size the core geospatial companies. We explore the specific sectors that contain geospatial companies below.

Focusing only on companies whose core activity is the supply of geospatial data will, by definition, exclude many companies for which geospatial data is a component of activity but not the only component. However, including all companies which use geospatial data to any extent would exaggerate the size of the market as it would include companies which could still offer their main goods and services without geospatial data. These companies are not as relevant for understanding the geospatial data market.

In addition, we did not include all companies which manufacture devices that can capture geospatial data. We took the view that only those organisations whose devices are used exclusively to capture geospatial data should feature in our estimates. This means that the manufacturers of drones used primarily for leisure or media activities are not included, but drone manufacturers which build drones used for agricultural surveys are included. This distinction is not always straightforward, and our rules are set to try and capture these differences.

Finding all of the relevant companies once the definition has been set was also not straightforward as no single comprehensive data source exists. To overcome this challenge, we used new tools, such as the AI web reading service provided by glass.ai, to identify companies and expanded existing methodologies of key word searches to cover multiple platforms.

Identification was especially difficult for large companies where a part of their business relies heavily on geospatial data but the whole company does not. International companies like Google carry out a significant amount of geospatial activity and are also involved in other sectors of the economy. This is particularly common in the digital sector where many companies are involved in multiple strands of interrelated activity. Unless a company was identified via our key word searches, we did not include it in our market-sizing estimates even if we know that the overall organisation carries out some relevant geospatial activity. We discuss the impact of this in further detail in the following section.

[61] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/785547/unlocking_digital_competition_furman_review_web.pdf

3.1.1 Limitations of metrics data

Our approach to identifying and sizing geospatial activity is robust and transparent. However, there are limitations in what we can infer about the size of the ecosystem. In particular, the four identification datasets we use[62] should give a comprehensive and representative view of the market. Despite this, there will be companies that are not captured in these datasets and therefore not included in our analysis.

Our focus is on core suppliers of geospatial data. We do not provide sizing metrics for companies in the wider ecosystem identified through the other lists or for organisations that use geospatial data internally. This is outside the scope of this report.

The financial metric, turnover, which we use to estimate the size of the market, does not capture the spillover effects that we previously discussed. Also, financial metrics are not available for all companies that we identified. This is most often the case where the company is small and is exempted from providing this information as part of annual accounts, for example.[63] It can also be the case that there is a gap in the underlying data source for other reasons.[64]

In the following two subsections we examine the size of the geospatial market and the characteristics of firms active in this ecosystem.

3.2 What can we say about the size of the market?

In total, across the datasets, we identified almost 2,000 companies for which the supply of geospatial data is a core activity and 500 projects with a core geospatial focus. For context, there were over 2.7 million firms paying VAT or PAYE in the UK in 2019.[65]

As well as the number of companies and projects identified, we examined the size of the market in terms of the annual turnover, grant funding and employment figures.

3.2.1 Annual revenue

In 2018 the total turnover across the companies identified was £6 billion, with data only available for around 30%[66] of all companies identified. This is a conservative estimate for several reasons:

- Small companies benefit from certain reporting exemptions which mean not all turnover data is reported.

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62 Beauhurst, Bloomberg, glass.ai and UKRI.

63 Companies do not need to file if they meet two of: annual turnover of £10.2 million or less; balance sheet of £5.1 million or less; no more than 50 employees on average.

64 We use 2018 turnover data throughout as 2019 data is less complete.

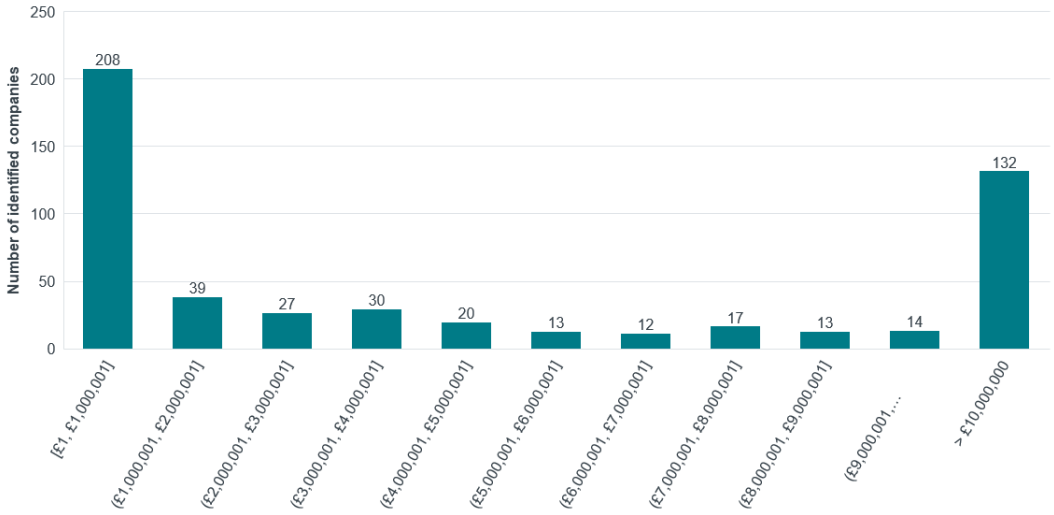
65 There are over 2.7 million firms paying VAT or PAYE in the UK. This may exclude a number of very small firms.

66 This excludes companies incorporated in 2019 and 2020 but includes all companies incorporated in 2017. This is an underestimation of the number of companies with turnover data in 2018 as it does not exclude inactive/exited companies from the denominator. Our data extraction did not provide the year of inactivity/exit. If all those marked as inactive in the FAME data were inactive by 2018, then we have turnover data for 40% of the companies identified.

- While we endeavoured to be as comprehensive as possible, it is unlikely that our methodology was able to identify every single core geospatial company in the UK.
- We excluded some companies which met our search and tiering criteria because on manual review we did not believe that they met our core definition. However, parts of these excluded companies will depend on geospatial data and our turnover metric does not account for this.

We identified firms with a range of different turnover levels. Nearly 40% of companies (with turnover data available) had a turnover of under £1 million and around 25% had a turnover in excess of £10 million in 2018. The remaining 35% of firms had turnover of between £1 million and £10 million. We show the 2018 distribution of turnover in Figure 10.

Figure 10 Core geospatial firms 2018 turnover



Source: Frontier analysis based on data from Beauhurst, Bloomberg, glass.ai and FAME
Note: Turnover data was available for around 30% of companies in 2018.

In the Bloomberg dataset, which covers large publicly listed companies, the top companies by turnover are in metals and mining, such as Metals Exploration[67] and NQ Minerals.[68] The top turnover companies that we identified in Beauhurst data cover fast-growing SMEs and include construction companies (e.g. GRAHAM Group[69]) as well as fleet management/vehicle location companies (FMG[70]). Those identified by glass.ai have some overlap with the Beauhurst companies but also include companies from environmental/planning data (Landmark Information[71]) and mapping (Freedom g-map[72]). Companies with relatively high turnover

67 https://metalsexploration.com/
68 https://www.nqminerals.com/
69 https://www.graham.co.uk/
70 https://www.fmg.co.uk/
71 https://www.landmark.co.uk/
72 http://www.freedom-group.co.uk

identified through relevant geospatial projects funded by UKRI include transport companies like FirstGroup[73] and TRL.[74]

3.2.2 Grant funding

The UKRI data provides information on funding to support geospatial research projects. Specifically, we examined the extent to which our sample of firms were in receipt of grants from UKRI to support innovative geospatial research and development projects.

We identified almost 500 UKRI-funded projects that featured commercial geospatial commercial. The total value of these grants from 2005 to 2020[75] was £267 million. In 2019, the total value of grants was £61 million, with 101 grants started (project has commenced). Most of these grants were for collaborative R&D[76] and feasibility studies.[77] The average grant size was £600,000 in 2019. Companies that received the highest value grants tended to focus on mobility issues and included companies like Oxbotica[78] and Fusion Processing.[79]

The Beauhurst data also provides information on grant funding. There is likely to be an overlap with the grant funding in the UKRI data and so we present the findings separately. The Beauhurst data shows a total of 806 grants to geospatial companies with a combined value of £154 million. Around a third of Beauhurst companies received at least one grant. These companies received an average of three grants each. The average grant size was under £200,000, which is much smaller than the average grant size in the UKRI data, possibly due to a wider range of funder organisations covered by Beauhurst. Companies which received the most in total grants also included mobility companies like Oxbotica, but other sectors like precision agriculture are in the top ten companies by total grant value.

3.2.3 Employment in geospatial firms

The datasets provide some indication of the number of people employed in the companies we identified. Across the datasets, we were able to collect employment information on two-thirds of the geospatial firms in 2019.

We found that over 115,000 people were employed (headcount) by this subset of organisations in the most recent data from Beauhurst, FAME and glass.ai.[80] 60% of companies had 10 or fewer employees and around 90% had under 100 employees (Figure 11).

[73] https://www.firstgroup.com/

[74] https://trl.co.uk/

[75] We extracted the data in spring 2020, at which point eight relevant projects were identified. This is not a full year of data.

[76] Collaborative R&D projects are awarded through competitions run by Innovate UK. They require collaboration between businesses and/or between business and academics.

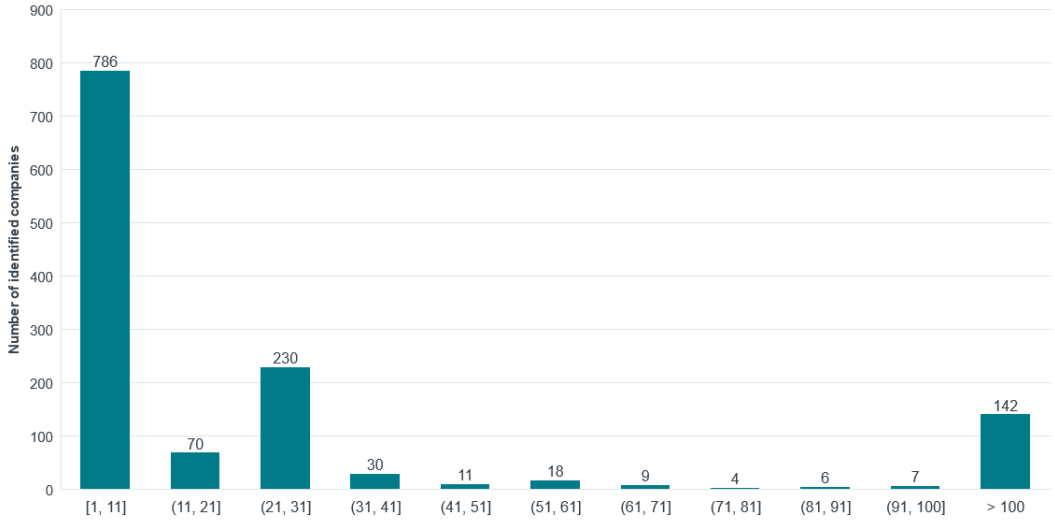
[77] Feasibility studies are an analysis and evaluation of a project's potential, designed to aid decision making. Individual competitions run by Innovate UK will specify their requirements for project size and length,

[78] https://www.oxbotica.com/

[79] https://www.fusionproc.com/

[80] This data was not available to export from the Bloomberg platform

Figure 11 Core geospatial firm 2019 employment



Source: Frontier analysis of Beauhurst, glass.ai and FAME data

Note: Employee numbers by headcount.

3.2.4 Market entry of geospatial companies over time

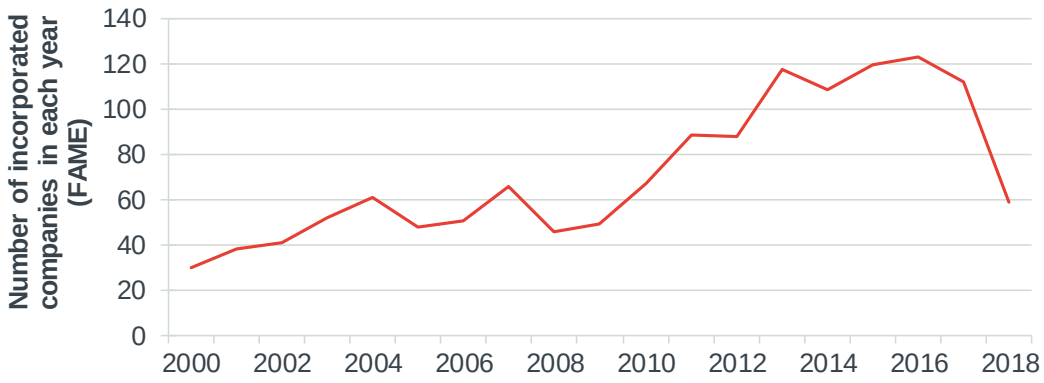
Exploring changes over time allows us to identify trends in ecosystem growth.

We examined the year of incorporation for all geospatial firms that are matched into the FAME data. We can clearly see an increasing number of entrants into the geospatial ecosystem over time, although the growth rate has been slowing in the past few years and decreased in 2017 and 2018. We present this trend in Figure 12. This trend is in keeping with existing evidence. An innovation survey carried out by BEIS (2019)[81] found that the proportion of companies which were engaged in innovation fell between 2014-16 and 2016-18. If this is a wider trend, some form of action may need to be taken to determine why this is the case and to explore potential solutions.

It is important to note that this rate of firm entry does not represent overall growth in the number of relevant companies. This is because we cannot capture firms which may have been present in earlier years but have subsequently exited the market and were therefore not identified via our search term methodology.

[81] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/903582/UK_Innovation_Survey_2019_Main_Report.pdf

Figure 12 Number of geospatial companies created in each year by year of incorporation: FAME data 2000-2018

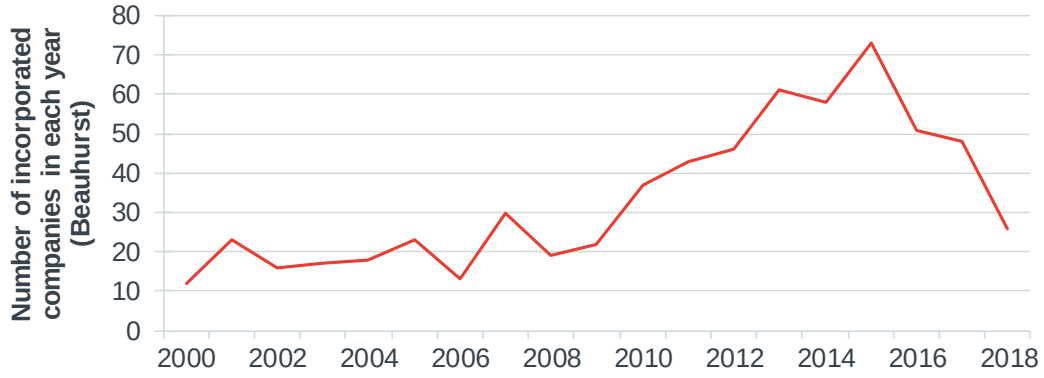


Source: Frontier analysis

Note: Not all companies were matched to FAME data.

We see a similar trend for SMEs in the Beauhurst data, presented in Figure 13, although the downward trend in recent years is more pronounced.

Figure 13 Number of geospatial companies created in each year by year of incorporation: Beauhurst data on SMEs 2000-2018



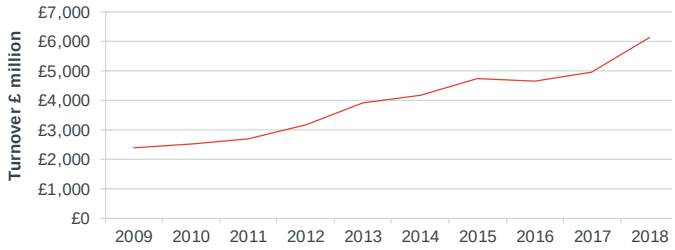
Source: Frontier analysis

Total annual turnover and employment over time

We extracted FAME data back to 2009, which allows us to look at changes to turnover and employee numbers over time. However, there are significant gaps in the data as small companies are exempt from some reporting requirements, so these figures should be taken as conservative estimates. Not all 2019 data has been reported and so we show trends in annual turnover through 2018. We see that both turnover (Figure 14) and employment (headcount) (Figure 15) have been rising since 2009, with large increases between 2012 and 2015 in particular. This

is due to the growth of existing geospatial firms over time and new geospatial firms entering the market.

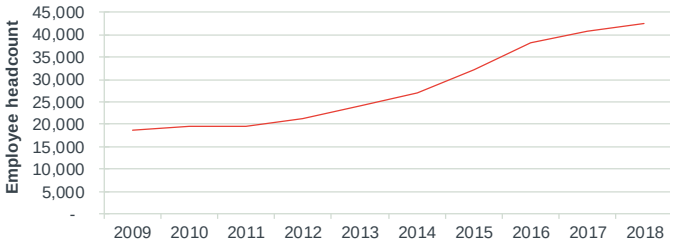
Figure 14 Turnover 2009-2018



Source: *Frontier analysis of Beauhurst, Bloomberg, glass.ai and FAME data*

Note: *We exclude turnover in 2019 as not all data has been published yet.*

Figure 15 Employment 2009-2018



Source: *Frontier analysis of Beauhurst and FAME*

Note: *Employment is measured by headcount. We exclude employment data in 2019 as glass.ai data was a snapshot in 2019 and provided employment data for over 200 companies with no employment data in FAME, and this would skew the trend.*

As we described above, in 2018 the total turnover across the companies identified was £6 billion, with data only available for around 30%[82] of all companies identified. Total turnover in 2009 was £2 billion. Therefore, the average annual growth rate was 10% over the period in question.

Grant funding over time

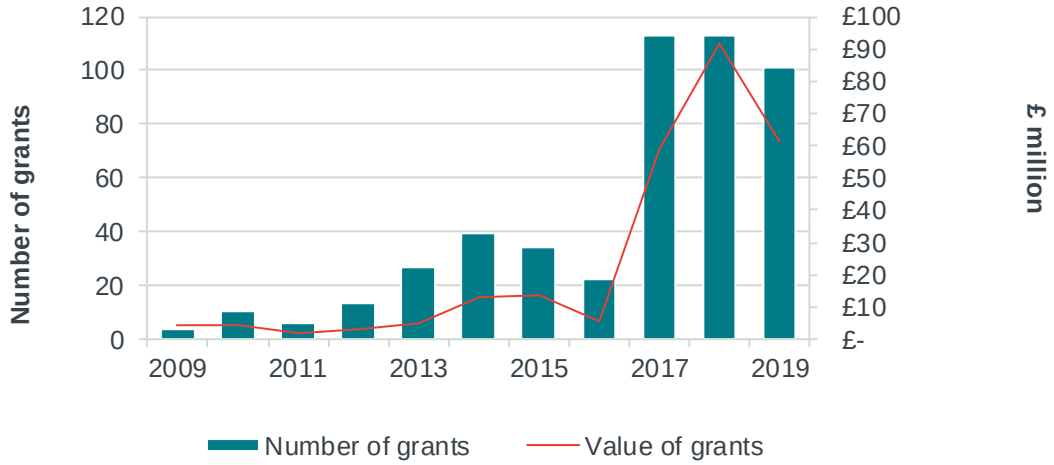
We also examined how many UKRI grants for geospatial projects were awarded in each year (Figure 16). Relatively few core geospatial projects were funded prior to 2009. From 2009 to 2016 an average of 19 relevant projects per year received grants. In 2017 this rose significantly to 113, increasing by over 500%. This coincides with the introduction of the Industrial Strategy Challenge Fund.[83] The number of UKRI grants (for all projects) rose from 7,580 in 2016 to 10,667 in 2017: an increase of just over 40%. It is too early to determine conclusively whether grant funding for geospatial projects will continue to be funded at this higher level in the future.[84]

[82] This excludes companies incorporated in 2019 and 2020 but includes all companies incorporated in 2017. This is an underestimation of the number of companies with turnover data in 2018 as it does not exclude inactive/exited companies from the denominator. Our data extraction did not provide the year of inactivity/exit. If all those marked as inactive in the FAME data were inactive by 2018, then we have turnover data for 40% of the companies identified.

[83] The Industrial Strategy Challenge Fund is part of the Industrial Strategy, which is the government's plan to raise productivity and earning power in the UK in the long term. The fund is a key part of the £4.7 billion committed to R&D funding over four years. The fund started in late 2016. https://www.ukri.org/innovation/industrial-strategy-challenge-fund/#pagecontentid-0

[84] We extracted the data in spring 2020. We therefore identified some geospatial projects that received funding in 2020 but, as this was not a full year of data, we do not include these in the graph.

Figure 16 UKRI grant funding 2009-2019



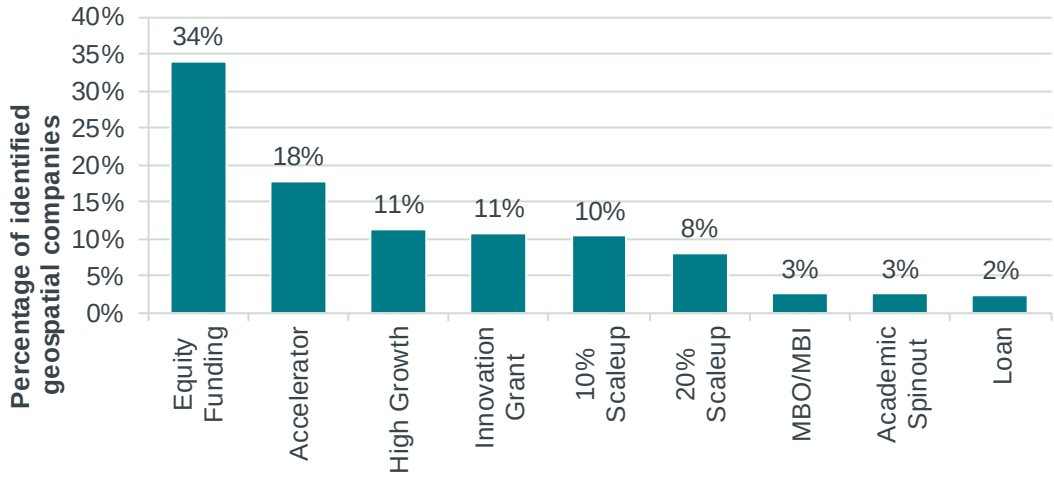
Source: *Frontier analysis of UKRI data*

Note: *By year the grant started.*

3.2.5 SME growth activity

The Beauhurst dataset focuses on SMEs that are fast growing or ambitious. Beauhurst tracks companies that meet one of eight criteria, which relate to the type of funds raised, innovation grants, growth, scaleups, management buyouts/ins, accelerator attendance and academic spinouts. Just over half the geospatial firms we identified were included in the Beauhurst tracking database because they received equity funding or participated in an accelerator attendance. Further details on the Beauhurst tracking criteria are provided in Annex B.6.

Figure 17 Beauhurst companies by tracking reason



Source: *Frontier analysis*

Note: *Note that a company may be tracked for more than one reason. MBO/MBI are management buyouts/ins.*

Accelerators are important for some geospatial firms

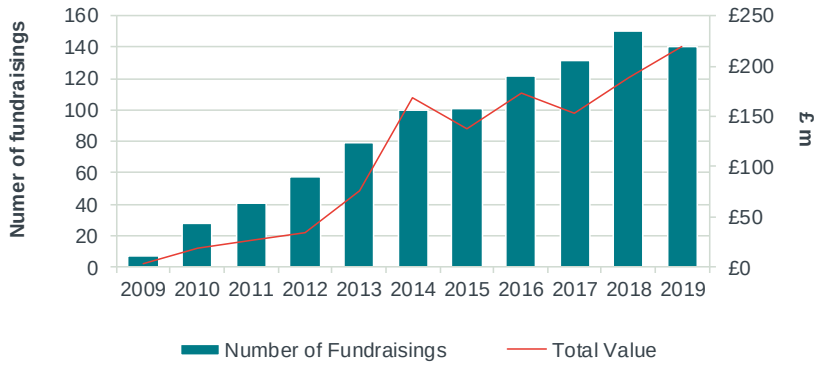
The Beauhurst data provides information on the extent to which our geospatial firms have interacted with accelerators that aim to help small organisations grow.[85] Some of the interviews in our qualitative engagement highlighted that attending an accelerator had a material impact on their success.

Of the Beauhurst companies identified, 25% attended an accelerator.[86] Some of these companies attended multiple accelerators: 22% attended two and 8% attended three or more.

Fundraisings over time

The Beauhurst data also provides information on fundraisings by the companies it tracks. Through 2019, the 840 companies we identified in Beauhurst had over 900 fundraisings, which raised over £1 billion. In Figure 18 below we show how the number and value of fundraisings have generally been increasing over time.

Figure 18 Number and value of fundraisings in Beauhurst data 2009-2019



Source: Frontier analysis

Companies that have raised the most funding include Citymapper,[87] a transportation planning app, and GeoSpock, a big-data platform.[88] The average (mean) value of a fundraising was £1.25 million but the median was much lower at £210,000, suggesting that there are a relatively small number of very large fundraisings.[89]

For comparison, we reviewed trends in the number and value of fundraisings for a selection of firms operating in comparable areas of the economy according to Beauhurst. Beauhurst uses buzzwords to place companies into a specific theme,

[85] Examples of accelerators include Seraphim Space Camp, GeoTech Programme and Cognicity Challenge.

[86] This is different to the 18% of identified companies that are tracked by Beauhurst because of accelerator attendance. This is because companies can be tracked for multiple reasons: the data shows a total of 1,175 reasons for tracking across 840 companies.

[87] https://citymapper.com/london?lang=en

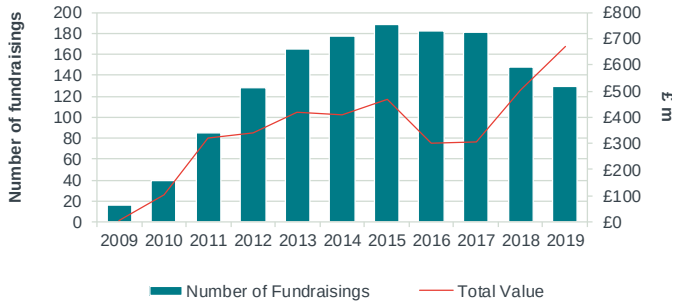
[88] https://geospock.com/en/

[89] The median figure is for fundraisings in 2005-2020. It was not possible to extract the figure for only 2009-2010.

which can be a particular technology or application.[90] We looked at companies that are tagged to certain buzzwords and sectors where there are overlaps with some geospatial data companies:[91] adtech, proptech, drones and artificial intelligence for buzzwords, and aerospace, automotive and mobile apps for sectors.

Across the buzzwords we see a similar general trend of an increase in the number and value of fundraisings from 2009 to 2019, with proptech and artificial intelligence growing at higher rates in the past few years.

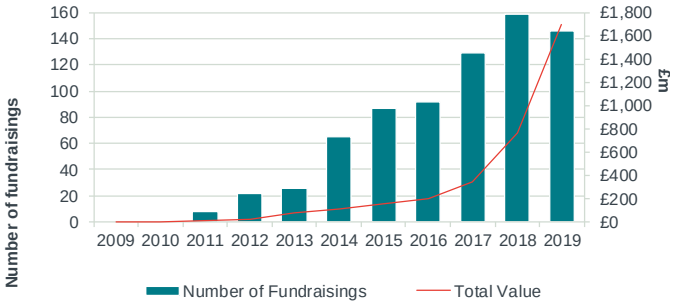
Figure 19 Adtech fundraisings



Source: Frontier analysis

Note: There are 869 companies tagged to Adtech.

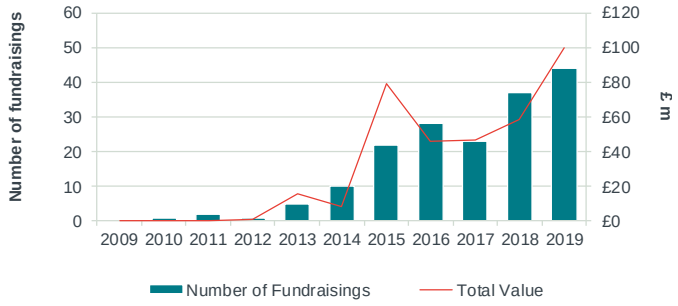
Figure 20 Proptech fundraisings



Source: Frontier analysis

Note: There are 415 companies tagged to Proptech.

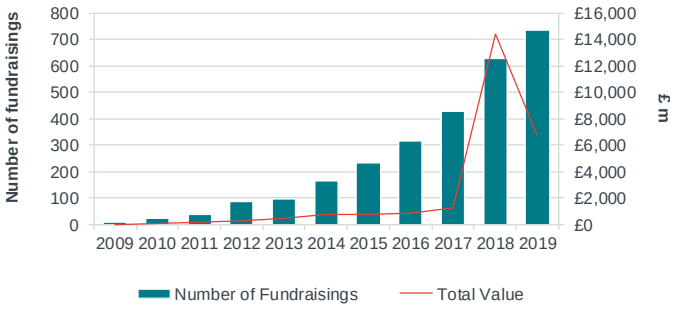
Figure 21 Drones fundraisings



Source: Frontier analysis

Note: There are 164 companies tagged to drones.

Figure 22 Artificial intelligence fundraisings



Source: Frontier analysis

Note: There are 1,843 companies tagged to artificial intelligence.

There are similar upwards trajectories for the aerospace, automotive and mobile app sectors.

For all companies that are tracked by Beauhurst, there has been a general trend of increasing numbers of fundraisings and increasing total values. This shows that geospatial companies are following broad patterns that we see across comparable sectors and buzzwords, but with smaller numbers of fundraisings currently (with the exception of drones).

[90] Buzzwords are curated by Beauhurst through its identification of trends in media and emerging technology spaces. They reflect current and "hot" topics that have received high levels of recent interest. Some buzzwords, like Artificial Intelligence, will span multiple sectors but others will describe very niche areas within a sector. Buzzwords are not relevant for all companies tracked by Beauhurst, whereas all companies will be tagged to at least one sector.

[91] A company can be tagged to multiple buzzwords and sectors so there will be overlap in the companies across the comparison sets

Pre-/post-money valuations

The Beauhurst platform also provides statistics on the average pre- and post-money valuations. This allows us to see what the impact of the fundraising was on the valuation of the company. An increase in post-money valuation suggests that investors see the company as more valuable than before fundraising, with larger percentage increases representing higher company values. This is a proxy for the uplift in value that geospatial companies command, and therefore the extent to which geospatial companies are rising in value relative to other sectors.

For geospatial companies, the average increase in the post-money valuation is 20%. This is higher than the average increase across the buzzword companies and companies in comparable sectors. This may be because geospatial firms are smaller on average and are therefore experiencing more rapid growth in percentage terms. We present these comparison points below (Figure 23), along with the figures for all companies tracked in the Beauhurst platform.

Figure 23 Differences in pre- and post-money valuations for selected buzzwords and sectors

Buzzword/sector	Percentage increase in post-money valuation
Geospatial	**20%**
Adtech	17%
Proptech	15%
Drones	24%
Artificial Intelligence	15%
Buzzword average	**18%**
Aerospace	11%
Automotive	20%
Mobile apps	14%
Sector average	**15%**
All tracked companies	14%

Source: Frontier analysis

Note: Different periods underlie the pre- and post-money valuations: e.g. all tracked companies is the period 1999-2020 and mobile apps is 2004-2020.

3.2.6 Large companies that carry out some geospatial activities

We do not include large firms for which geospatial data underpins certain activities if they were not identified through our search term methodology (such as those found in Bloomberg) in our core geospatial dataset. This is because, while geospatial data may underpin some activities of companies like Apple, Google and Amazon, not all of the revenue can be attributed to the use of geospatial data. And, as these companies are so large, including them would materially affect the sizing metrics and distort the estimate of the ecosystem size.

Additionally, there were companies identified only through UKRI data that were involved in projects which met our core criteria but the company itself was not a

core geospatial company.[92] We include these core projects but we do not include these companies in our core company list. If we included 1% to 10% of this turnover, it would increase our estimate by between £0.8 and £7.9 billion.

However, this necessarily underestimates the size of the geospatial data ecosystem. To illustrate this, we examined the total volume of worldwide R&D spending carried out by selected large companies which undertake some level of geospatial activity. A huge amount of geospatial innovation is already taking place within these companies and across the ecosystem. For illustration purposes, we show the impact of attributing a small proportion of this spend to the UK's geospatial data market (Figure 24). We can see that £0.5 billion to £5.3 billion of activity could be included if 1% to 10% of the R&D at large companies can be attributed to geospatial data. Clearly, including even this small proportion of R&D spend in our estimates of market size would have a significant impact. For the sake of illustration, if we added this R&D range to our estimate of market turnover, our market size would rise to between £7bn and £11bn. This still is an underestimate as we do not include the R&D spend of other large companies that use geospatial data in some way.

Figure 24 Illustrative analysis of percentage of 2018 R&D spend of large companies attributable to geospatial data, £ billion

Company	1%	5%	10%
Amazon	£0.17	£0.85	£1.70
Alphabet/Google	£0.12	£0.61	£1.22
Microsoft	£0.09	£0.46	£0.92
Apple	£0.09	£0.44	£0.87
Facebook	£0.06	£0.29	£0.59
Total	£0.53	£2.64	£5.29

Source: https://www.strategyand.pwc.com/gx/en/insights/innovation1000.html; exchange rate 2018 average from https://www.irs.gov/individuals/international-taxpayers/yearly-average-currency-exchange-rates .

Large companies like these may also acquire specialised geospatial companies rather than investing in their own capabilities through R&D. In our SME analysis, we found that 3% of geospatial companies identified in the Beauhurst data were tracked due to management buyouts/ins. While it is outside the scope of this report to analyse this trend in detail for the companies doing the acquisitions, we provide two illustrative examples of where this has occurred recently:

- Insurity, a provider of data and cloud services for the insurance sector, acquired SpatialKey in late 2019.[93] SpatialKey specialises in geospatial analytics.
- Facebook acquired Mapillary, a Swedish mapping start-up, in 2020 as part of Facebook's open mapping efforts.[94]

An alternative measure is to look at the total size of the digital technology market in the UK and apportion some of this to geospatial data. This is relevant given how

[92] We excluded all companies identified only through the UKRI data (i.e. not found in Beauhurst, Bloomberg or glass.ai datasets) which had turnover of more than £50 million in any year from 2009 to 2019.

[93] https://www.insurity.com/announcement/insurity-acquires-spatialkey-inc-a-leader-in-pc-geospatial-analytics/

[94] https://blog.mapillary.com/news/2020/06/18/Mapillary-joins-Facebook.html

cross-cutting and embedded geospatial data is throughout the economy, including the digital technology market. If even 5% of turnover in this market were attributed to geospatial data, this would correspond to £9.2 billion.[95]

We also note that most of the companies identified in the Bloomberg data are from mining and mineral exploration (82%). While these activities require geospatial data, it is likely that a significant proportion of the turnover could be unrelated to the activities requiring geospatial data. If we removed these companies from our core dataset then the total 2018 turnover would fall by around £100 million.

3.3 Sectors and locations of geospatial firms

We reviewed the sectors and locations of the companies identified in our core list to better understand the characteristics of these core geospatial companies.

3.3.1 Sectors of core geospatial companies

The different datasets we use do not have a consistent sectoral classification. Beauhurst and glass.ai have bespoke classification systems and FAME provides Standard Industrial Classifications (SICs), which are used by the Office for National Statistics (ONS) to classify businesses according to the type of economic activity in which they are engaged. [96]

Core geospatial firms (and the wider ecosystem) will not all be included under a single ONS SIC code class or an individual division or group. This is because geospatial activity is an enabler across the entire economy. For example, some geospatial data-related activities can be found in a SIC code covering *surveying and mapping*, while other companies may be captured by the *data processing, hosting and related activities* code.[97] These two codes will definitely feature clusters of geospatial firms. However, our analysis shows that geospatial activity is spread across the entire economy.[98]

The FAME dataset contains the most complete indication of identified firms' areas of economic activity by SIC code across all the datasets. Overall, 83% of all companies identified have a SIC code from FAME data.

The top ten most frequent five-digit SIC codes in our FAME data account for 50% of the companies matched with FAME data (Figure 25).

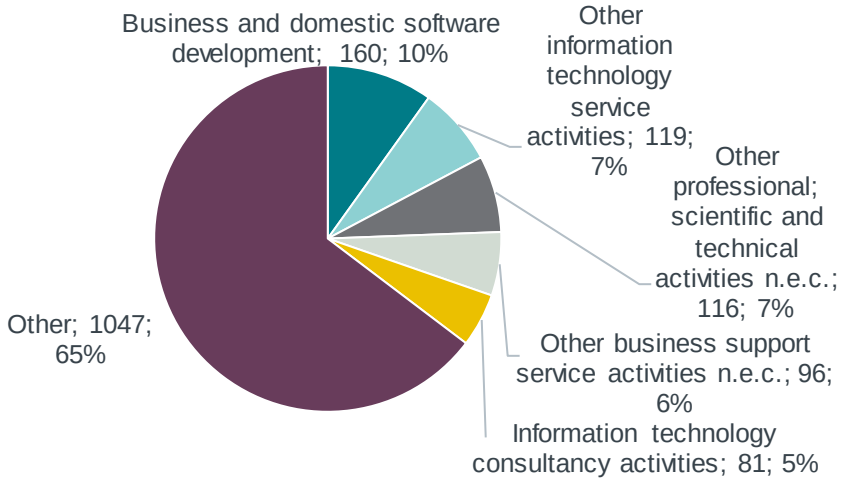
[95] Size of the UK technology market taken from Technation EY report https://technation.io/wp-content/uploads/2018/05/Tech-Nation-2018-press-release-1.pdf

[96] The SIC is divided into 21 sections (e.g. manufacturing), which are then further broken down into 88 divisions (manufacture of textiles), 272 groups (manufacture of other textiles) and 615 classes (manufacture of carpets and rugs). In some cases, classes are also broken down into subclasses. Further detail is available here: http://resources.companieshouse.gov.uk/sic/

[97] SIC code 71.12/2, which comprises of a broad range of surveying and mapping services and contains cartographic and spatial information activities. In addition, companies which carry out data processing, hosting and related activities are included under SIC code 63, although geospatial is not separated out explicitly.

[98] This is true even with the Tier 2 rules restricting identification to a list of relevant sectors.

Figure 25 Top five SIC codes in FAME data: counts and percentages

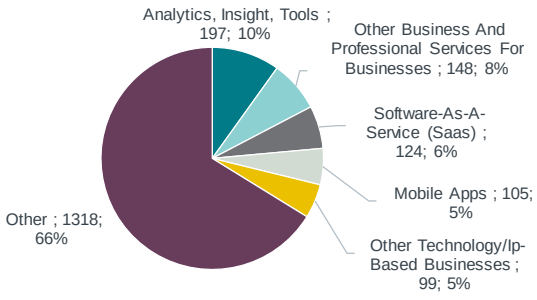


Source: Frontier analysis of FAME data

This illustrates the wider range of sectors that core geospatial data companies are in and further demonstrates the difficulty in isolating the geospatial element within a single traditional market. This was part of the evidence base which led us to conclude that it is more accurate to refer to a geospatial data ecosystem. The most common sectors include software development, IT services, natural sciences, architecture and engineering.

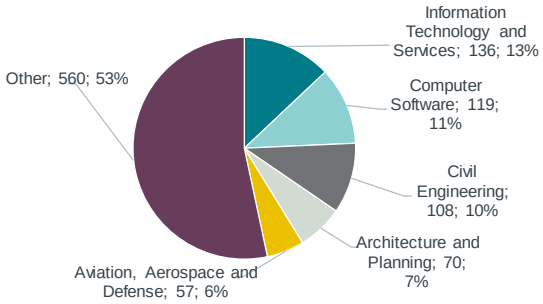
We found similar sectoral patterns across the Beauhurst (Figure 26) and glass.ai platforms (Figure 27), which feature different sector definitions. These results are not directly comparable with each other or SIC codes, but we can see a significant proportion of firms identified in software, analytical and engineering sectors. We also found clusters of firms in fossil fuel industries, telecommunications and land management.

Figure 26 Top five Beauhurst sectors: counts and percentages



Source: Frontier analysis of Beauhurst data

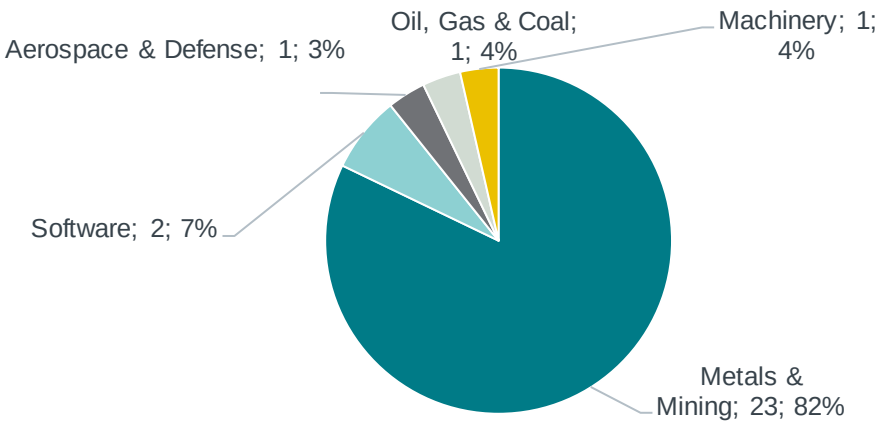
Figure 27 Top five glass.ai sectors: counts and percentages



Source: Frontier analysis of glass.ai data

The companies identified from Bloomberg are predominantly in metals and mining. Other sectors which appear include: aerospace and defence; software; oil, gas and coal; and machinery. We present all companies' sectors below (Figure 28) as only 28 companies were identified in the Bloomberg data.

Figure 28 All Bloomberg sectors: counts and percentages



Source: Frontier analysis of Bloomberg data

The most common sectors identified across the platforms have some overlap with the five themes of private sector use cases identified by the Geospatial Commission in the "Initial Analysis of the Potential Geospatial Economic Opportunity" (Cabinet Office, 2018)[99] which were:

- sales and marketing;
- property and land;
- infrastructure and construction;
- mobility; and
- natural resources.

We compared this to the most common sectors for UK firms as a benchmark. We can see that the sectoral breakdown of geospatial firms differs from the overall distribution of all UK firms. In Figure 29 we compare the percentage of geospatial firms appearing in the ten SIC code divisions that contain the highest number of these firms (a higher-level sector classification than the SIC codes presented above) with the percentage of all UK companies in these divisions. We see that geospatial firms are over-represented in sectors such as computer programming, professional and technical activities, and engineering relative to all UK companies.

[99] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/733864/Initial_Analysis_of_the_Potential_Geospatial_Economic_Opportunity.pdf

Figure 29 Top ten SIC divisions for geospatial companies compared to all companies

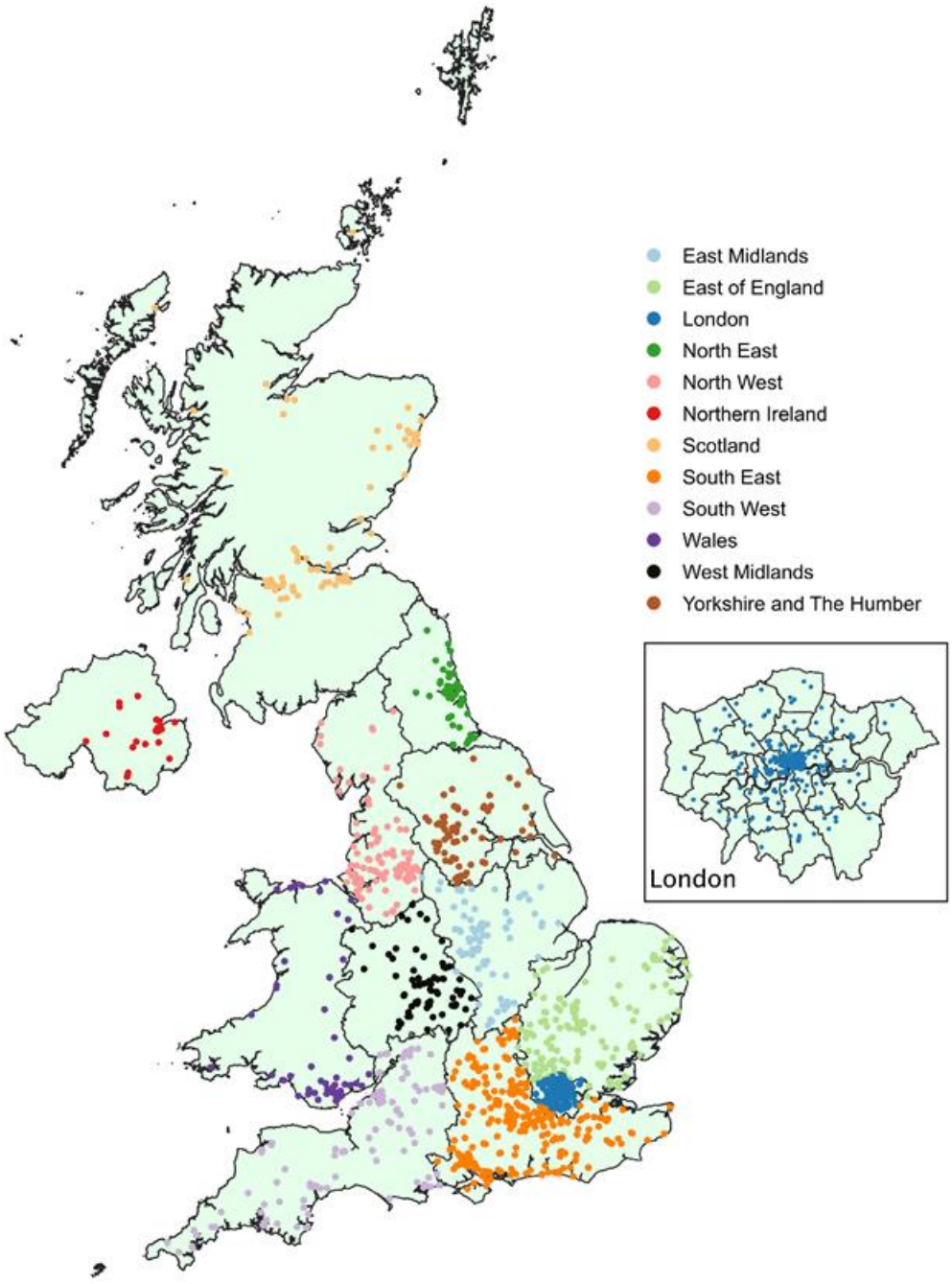
SIC division	Geospatial companies (FAME data)	All UK companies (ONS data)
Computer programming; consultancy and related activities	23%	6%
Other professional; scientific and technical activities	11%	3%
Architectural and engineering activities; technical testing and analysis	10%	4%
Office administrative; office support and other business support activities	6%	5%
Activities of head offices; management consultancy activities	5%	7%
Scientific research and development	4%	0%
Information service activities	4%	0%
Manufacture of computer; electronic and optical products	3%	0%
Specialised construction activities	3%	8%
Telecommunications	3%	0%

Source: Frontier analysis of FAME data and https://www.ons.gov.uk/businessindustryandtrade/business/activitysizeandlocation/datasets/businessdemographyreferencetable

3.3.2 Location of core geospatial companies

We examined where core geospatial companies are located within the UK using available location indicators in our datasets. In total, over 90% of firms in our sample have a location associated with them in at least one dataset. Figure 30 shows the distribution of core geospatial companies identified through our analysis that had location information. We see that our identified geospatial companies are spread widely across the UK with some specific clusters in London and the South East. This is not surprising and is generally reflective of economic activity patterns across the country, with every region being represented.

Figure 30 Distribution of UK core geospatial companies



Source: Frontier & Geospatial Commission analysis of FAME, glass.ai, Beauhurst data

The Beauhurst dataset (which focuses on small, fast-growing companies) contains head office location information for 42%[100] of our sample. From this platform we can see that there is also a clear clustering around London and the South East. This is, again, not surprising, and is generally reflective of the economic activity patterns across the country. However, there is a spread of geospatial companies across the UK, and every region is represented to some extent. London and Scotland have a disproportionately higher concentration of geospatial companies relative to their share of overall companies.

Figure 31 Beauhurst head office location of geospatial firms compared to ONS location data of all UK firms by percentage

Head office region	Geospatial companies (Beauhurst)	ONS – all companies
London	28%	19%
South East	14%	15%
East of England	9%	10%
Scotland	9%	7%
North West	7%	10%
South West	7%	9%
Yorkshire and The Humber	5%	7%
East Midlands	5%	7%
West Midlands	5%	8%
North East	4%	3%
Wales	4%	4%
Northern Ireland	3%	3%

Source: Frontier analysis; https://www.ons.gov.uk/businessindustryandtrade/business/activitysizeandlocation/bulletins/ukbusinessactivitysizeandlocation/2019;

[100] 97% of companies identified in Beauhurst have Beauhurst location data.

We see similar patterns in the FAME and UKRI data, as presented in Figure 32.

Figure 32 Regional locations in FAME, UKRI and ONS

Region	FAME head office	FAME primary office	UKRI	ONS – all companies
London	22%	17%	27%	19%
South East	19%	20%	22%	15%
East of England	11%	11%	7%	10%
Scotland	8%	8%	4%	7%
North West	8%	8%	8%	10%
South West	7%	8%	8%	9%
East Midlands	6%	7%	9%	7%
West Midlands	5%	6%	8%	8%
Yorkshire and The Humber	5%	6%	3%	7%
North East	4%	4%	2%	3%
Wales	3%	4%	1%	4%
Northern Ireland	2%	2%	1%	3%

Source: Frontier analysis; https://www.ons.gov.uk/businessindustryandtrade/business/activitysizeandlocation/bulletins/ukbusinessactivitysizeandlocation/2019;

Note: UKRI projects with no location data have been excluded.

However, this high-level regional view hides some more granular variation within regions. We used Beauhurst data to examine the top ten local authorities which have the highest number of core geospatial companies (see Figure 33 below).

Figure 33 Top ten companies by difference between the percentage of geospatial companies in the LA compared to percentage of all companies in the LA

Head office local authority	Geospatial companies (Beauhurst)	ONS – all companies
Islington	5%	1%
Westminster	4%	2%
City of London	3%	1%
Camden	3%	2%
Southwark	3%	1%
City of Edinburgh	3%	1%
Hackney	3%	1%
Vale of White Horse	2%	0%
Glasgow City	2%	1%
South Cambridgeshire	2%	0%

Source: Frontier analysis

This list includes London boroughs as well as cities in Scotland and other research and innovation hubs in Cambridgeshire and Oxfordshire. The top 20 local authorities include further geographic variation and feature Belfast, Aberdeen City, Glasgow City and Cardiff.

4 STRUCTURE OF THE GEOSPATIAL DATA MARKET

In this section we explore the following questions:

- What does the geospatial data market look like?
- What are the key value-adding activities undertaken by stakeholders in this market?
- What stages of the value chain are public and private sector organisations active within?
- What consumer-facing markets is the geospatial data market integrated into?

Understanding the geospatial market structure informed our choice of interviewees and informed the selection of questions we posed to highlight opportunities for further value creation. The insights relating to market structure we set out below reflect general responses which were raised by stakeholders across the market and through our market identification and sizing exercise. We provide more granular detail on specific sectors in our case study section (Section 6).

We found that:

- The geospatial data market consists of a large number of submarkets that carry out activity across the wider economy and therefore is described better as an ecosystem than as a traditional economic market. These markets can be subdivided into demand and supply. Supply-side stakeholders undertake a range of value-adding activities from collection of data to creation of insights and visualisations. Some supply-side organisations specialise in a specific niche within this value chain while others span the entire spectrum of activities.
- Geospatial market segments are linked to a range of commercial markets across the economy and geospatial data generates significant value for consumers across the UK.
- Collection and processing of geospatial information can be very costly and time consuming in some cases. Technological advances and associated reductions in costs have meant that some forms of geospatial data collection can now be undertaken by private sector organisations whereas previously this was not possible. However, other private sector supply-side stakeholders noted that they are planning to focus more on later-stage activities such as the production of geospatial solutions in the future. They told us that they hope to spend less time investing in data collection and cleaning. This was either because data collection was seen as low margin and therefore unattractive commercially or because participants had already made an upfront investment in data collection which they now wanted to focus on exploiting. For example, some firms described how they want to focus on developing services based on earth observation data for certain industry use cases rather than providing raw satellite data. Other organisations which traditionally focused on mapping products are now trying to create smart city solutions which are based on their underlying data sources.
- Public and private sector stakeholders co-exist in the same markets and value chains. The nature of these relationships varies as public sector actors can be

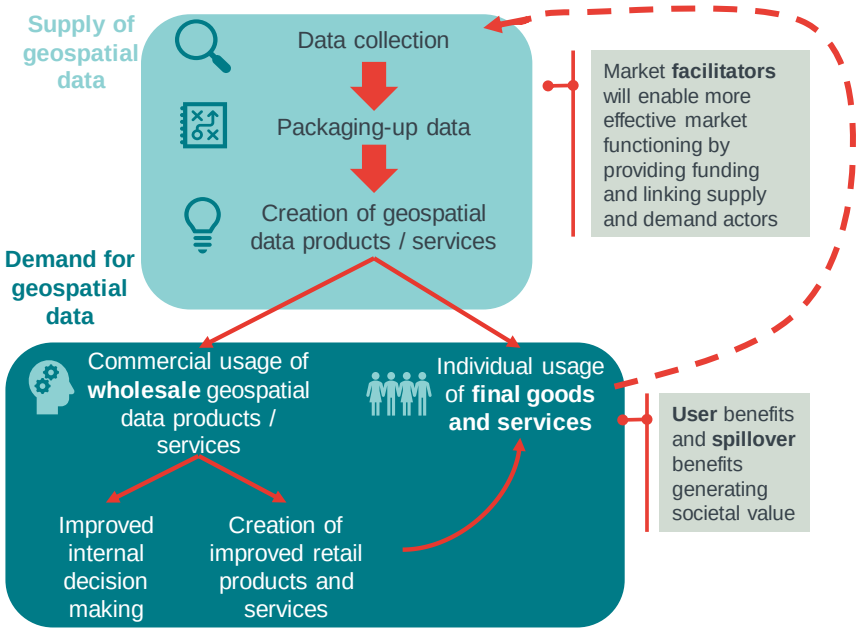
suppliers to the private sector, solution developers that compete with other private sector actors as well as customers for geospatial data products and services.

4.1 The geospatial ecosystem

As we set out in Section 2, we used our economic framework to visualise the geospatial ecosystem. Conventional market studies would segment a single market into supply- and demand-side stakeholders. Our market-sizing work shows that geospatial firms offer a range of diverse products and services which do not constitute a single market. This is because the vast array of different offerings are tailored to different use cases and sectors. As a result, consumers do not view them as being close substitutes. In addition, suppliers of these geospatial goods and services have developed specific forms of expertise, which limits the possibility of supply-side substitution.

Therefore, it is more appropriate to think of a geospatial ecosystem as containing many individual submarkets which are based on specific groups of products and services. We include a broad distinction between "supply" of geospatial data and "demand" within any specific geospatial market (Figure 34).

Figure 34 Ecosystem illustration



Source: Frontier

A number of activities sit within both the overarching supply and demand sides of each market. On the supply side, this includes data collection, packaging up data and the creation of geospatial data products and services. Building on previous research, we can further breakdown the relevant supply-side stages into the value chain structure shown below in Figure 35. This is a useful way to conceptualise the

provision of geospatial goods and services for our study and allows us to consider the role of specific stakeholder groups.[101] [102]

We can further divide this supply-side, value-adding process into five steps (Figure 35):

- Firstly, value is created via the **generation of geospatial data** via primary collection or acquisition.
- Next that **data is transformed** into a more useful format and is processed.
- This refined geospatial data is sometimes (but not always) **linked with other forms of information** which may or may not be geospatial.
- Commercial organisations may then use this aggregated and processed information good or service as a means to inform organisational decisions and **add value internally**.
- In other cases, the geospatial data may be included within a **retail product or service which is valued by end users**. In these cases, geospatial data forms a key intermediate good which is a component of a final good.

Figure 35 Simplified value chain

Source: Geospatial Commission and Frontier, adapted from Attard et al. (2016)

It is these products and services (both final and intermediate in nature) that constitute the relevant sets of economic markets. For example, one specific market in the geospatial ecosystem is the provision of mapping services to commercial users which are developing a consumer-facing application that includes a geographic contextualisation. There are multiple providers who offer variants of this service across both the private and public sectors.

These geospatial products and services vary in terms of their characteristics. Specifically, certain goods and services, such as a database of addresses and associated locations, are entirely geospatial in nature. Other goods and services include a geospatial element in addition to many other components such as an autonomous driving system which relies on a geospatial map as well as a range of other hardware and software. There is a spectrum ranging from purely geospatial goods and services at one end to goods and services where geospatial plays a limited role at the other end. The bundled goods and services link to numerous retail markets, which we describe below.

[101] Longhorn, Blakemore (2008), "Geographic Information, value, pricing, production, and consumption".

[102] Specifically, we adapted a series of data value-creation processes and techniques described by Brennan, Attard and Helfert (2018). Existing Commission research also highlights previous work by Spataro and Crow (2002), who developed a content management information value chain and Phillips (2001), who explicitly acknowledged that data will inform decisions which in turn will lead to value if these decisions lead to effective actions.

4.1.1 Spillovers in the geospatial ecosystem

Like many other forms of data, the value of geospatial data is not limited to the data creator or data user. Value from using geospatial data can be subdivided into several different categories based on who the value accrues to:

- Direct use value: where value accrues to users of geospatial data. This could include a sales and marketing firm using geospatial data to make better decisions and increasing profitability as a result.
- Use value: where value is also derived by indirect beneficiaries who interact with direct users. This could include other firms in the supply chain of the direct user or the firm's customers.
- Spillover use value: value that accrues to others who are not a direct data user or indirect beneficiary. This could, for example, include lower levels of emissions that generate health benefits to individuals which result from optimisation of the end-to-end supply chain of the direct user.

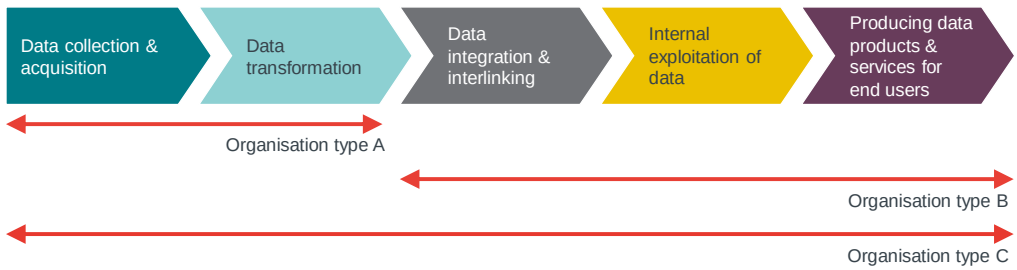
As the value from the geospatial data does not always accrue to the direct user of the data, there is a risk of underinvestment in geospatial technology and services

4.1.2 Placement of organisations across the value chain

We can group firms which are active in the geospatial ecosystem according to the stage of the value chain in which they are active. Some vertically integrated organisations span the entire value chain and cover all possible activities from the collection of data to the creation of solutions for end users, whereas other organisations focus on a specific niche within one of the five stages we described above.

In Figure 36 below we place three illustrative organisation types at different points of this value chain. These groupings are not intended to be exhaustive but illustrate some of the diversity in geospatial activity across the ecosystem. There is considerable diversity across individual value chains and the organisations active at different stages of activity. Our illustration below and examples of organisations help to highlight some of those distinctions.

Figure 36 Illustrative location of organisations across the geospatial data value chain



Source: *Frontier*

Note: *Example organisations do not directly correspond to any of the organisations we spoke to and are displayed for information only. These categories are not intended to be exhaustive.*

We spoke to multiple organisations in the public and private sectors which specialise in geospatial data collection and initial transformation. They fall under

Type A in our illustration above. These organisations include dedicated surveying companies which capture geospatial information using a variety of techniques or mobile network operators who can collect aggregated and anonymised geospatial data on their users' locations. These organisations then provide that data to others, usually as an intermediate good such as a datafile of journeys or a point cloud representing a building survey. These intermediate goods contribute to final goods in the transport or construction sectors, for example. Certain public bodies which are tasked with maintaining an up-to-date geospatial dataset covering a specific topic are also included within Type A.

Other organisations, which we classify as **Type B,** do not directly collect data themselves. Instead they ingest information produced by others and focus on the processing and linking of geospatial data sources in order to produce products and services for end users. This could include, for example, consumer-facing app providers who source data from public bodies to provide information on the location of amenities in an area.

A final group of organisations (**Type C**) are vertically integrated across the entire value chain. This group includes, for example, earth observation organisations which:

- have invested in their own data collection hardware;
- process the resulting raw imagery data using machine-learning techniques;
- combine multiple sources of information from different sensors; and
- create solutions for users in different industries. This could include use cases in the insurance sector which involve using geospatial information on flood risk to inform decision making.

It also includes public bodies whose remit involves the collection of geospatial information within a specific domain, the cleaning and processing of that data and the creation of solutions which are based on that information. These solutions may be for government to inform public service provision or for private sector clients to generate revenue.

Several public bodies that we engaged with noted that data capture was their primary activity. However, this is not true across the board as other partner bodies noted that they span the entire value chain. The majority of private sector actors we engaged with told us that they have at least some activity across all stages listed above but, again, this was not always the case.

Example of mobile network data value chain

Individual value chains can contain a large number of distinct organisations and stages. To illustrate this, we present an example value chain for mobile network data (we describe this in detail in Section 6.2)[103] which includes:

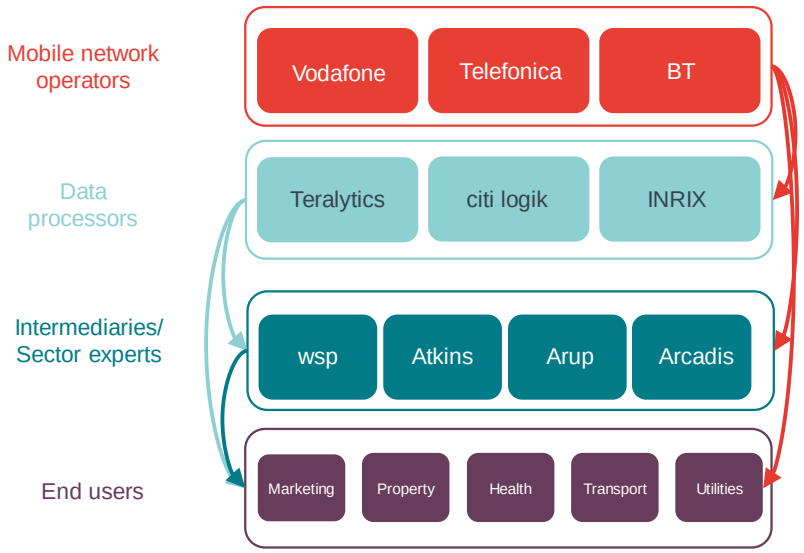
- Network operators who collect the raw data from the millions of devices interacting with their network;
- Data processors who clean the information and use the data to answer a specific question, which may relate to commuting patterns or exposure to out-

[103] Mobile network data is captured each time a device interacts with the mobile network. These interactions will occur when a user places a call or moves from the coverage of one mast to another.

of-home advertising. This includes organisations which use mobile network data (along with other sources) to answer questions for clients in the transport and smart cities sectors;

- Sector experts who help contextualise the mobile network data and include insights as part of a wider package of services which the end user values. This could include, for example, drawing in data from more traditional sources like traffic cameras or roadside interviews. This group includes organisations that incorporate insights from mobile network data as part of a wider package of support for end users, which could include technical advice relating to the deployment of infrastructure; and
- End users of the final products and services who are able to better understand day-to-day aggregated patterns of movement rather than relying on static snapshots or one-off surveys.

Figure 37 Mobile network data value chain



Source: Frontier

We provide more detail on the specific linkages between these different organisations and the underlying data flows in Section 6. At each stage of this value chain prior to final consumption, an intermediate geospatial product or service is produced. Many stakeholders described how their geospatial solutions are incorporated in this way into a range of different final goods across the economy.

4.2 Evolution of activity across the value chain

The geospatial data ecosystem is fast moving and dynamic whereas our visual representation of a value chain is static. However, our interviews allowed us to consider the evolution of the ecosystem as part of our qualitative engagement. Specifically, we were able to use the value chain illustration above to speak with market participants about their previous activities, current work and plans for the future.

We were told that in certain cases the emergence of new technologies or reductions in costs associated with certain activities, such as satellite or drone data

collection, means that a broader range of organisations are now able to engage in data capture. In some cases, this may previously only have been feasible for public sector bodies.

On the other hand, a key theme that emerged from our qualitative engagement related to the movement of some ecosystem participants towards the right-hand side of the value chain (i.e. the production of end products and services). Several private sector organisations told us they had recently started to shift towards the development of solutions and were devoting fewer resources to the collection of geospatial data or planned to do so in the future. This was either because they saw data collection as low margin and therefore unattractive commercially or because participants had already made an upfront investment in data collection which they now wanted to focus on exploiting. In some cases, organisations were moving their internal focus to accommodate this. In other cases, we were told that interviewees were partnering with other market participants to make this happen. For example, some firms described how they want to focus on developing services based on earth observation data for certain industry use cases rather than providing raw satellite data. Other organisations which traditionally focused on mapping products are now trying to create smart city solutions that are based on their underlying data sources.

Market participants thought they could generate more value at these later stages, which are more likely to include high margin activities. There was a view expressed that geospatial data capture may become commoditised in some cases (such as earth observation data) if widespread adoption led to the development of standardised products and inputs offered by multiple providers. This in turn could lead to a race to the bottom if consumers struggle to differentiate between high- and low-quality offerings, even if they are willing to pay for a higher-quality offering. Stakeholders noted that end users sometimes take the effort that goes into collecting and processing data for granted. This may be because they do not understand the complexity associated with each intermediate stage that leads to the creation of the end products, which they do value and are willing to pay for.

> We are increasingly looking at developing actionable solutions. That is where the value is.
>
> *Geospatial ecosystem participant.*

The Geospatial Commission could consider whether it would be beneficial to implement new policy designed to re-emphasise the importance of high-quality geospatial data which might help to overcome demand-side informational gaps.

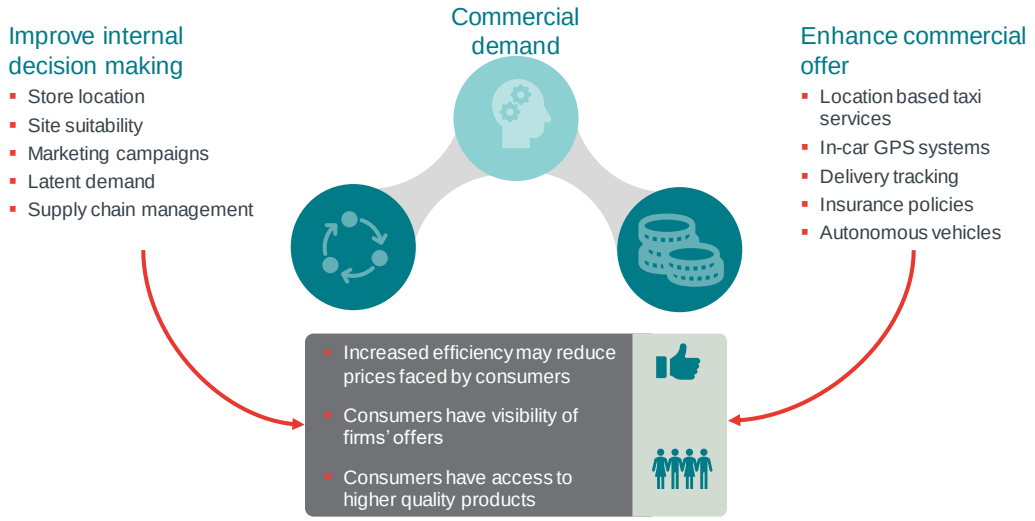
4.3 Demand for geospatial services and consumer benefits

As we set out in Figure 34, firms operating on the “demand” side use geospatial data products and services in a number of ways. These demand-side organisations are relevant to understanding the range of uses for geospatial data and the size of the economic prize that may be unlocked if uptake of geospatial data were

increased further. They largely sit at the right-hand side of the value chains we described in the previous section. They operate in their own economic markets across the economy such as insurance or retail. These demand-side organisations may use insights derived from geospatial data in two primary ways (Figure 38):

- **Improving internal decision making,** which may include usage of geospatial data to inform the location of future retail sites or the management of supply chains, for example; and
- **Enhancing their own commercial offering,** which could include, for example, the creation of new bespoke and targeted insurance policies which incorporate geospatial insights, or a location-based taxi service.

Figure 38 Further detail on commercial demand



Source: Frontier

These products can improve consumer welfare in a number of ways depending on the specific retail market that has included a geospatial input. Firstly, consumers are direct users of certain geospatial services which are highly valued by individuals. For example, consumers can use geospatial transport apps to plan their journeys. In other cases, consumers can use online portals to directly interrogate the risk of flood in their local area or examine geospatial information relating to their property.

More broadly, individuals benefit from public services which are more efficient or targeted as a result of being underpinned by geospatial data. Multiple partner bodies noted how their advice, products and services underpin key public services. This includes:

- distribution of rural grants;
- routing of public transport;
- collection of taxes; and
- national defence.

Geospatial data continues to play a vital role within government. It is used to inform public services and departmental decision making. Multiple partner bodies and devolved administrations told us that their primary role is to support the wider public sector in carrying out a defined activity, like tax collection, or providing advice on a specific area of geospatial data, such as sub-surface features and geoscience.

Other private sector organisations also cited government as an important client. For example, many local authorities purchase bespoke surveys based on aerial photography. This enables them to pick out granular details like building access points that can be used to inform service delivery. Also, many interviewees emphasised that the public sector response to COVID-19 has in part relied on geospatial data sourced from private sector providers who hold data on travel or movement patterns, for example. This all contributes to a more efficient and effective public sector.

We spoke to organisations which had customers in a wide variety of industries, including emerging areas such as:

- ***insurance*** where geospatial data can help organisations more accurately price risk and streamline claims processing; and
- ***healthcare*** where geospatial data can provide an indication of which individuals are using certain services and help to target resources in areas of acute need.

This is completely in keeping with our quantitative analysis to identify core geospatial firms, the results of which show that geospatial companies are spread across a wide variety of sectors.

Finally, consumers can also benefit when the firms they interact with use geospatial data to inform their decision making. Large retailers may use granular geospatial data on population demographics and store catchment areas. This information allows them to determine the location of new stores or decide the offerings to provide within an existing store. This results in better and more tailored choice for customers. Consumers in a specific area may otherwise have been underserved if lower quality geospatial data was used or firms relied on anecdotal or out-of-date evidence.

In some cases, demand for geospatial data can directly influence future supply. For example, we were told that some organisations do not realise the full value of the data they hold (which may arise as a by-product of other business activities like collecting information for tax purposes or the movements of an app's users) until they are approached by a potential user. These feedback effects can lead to the development of new products and services.

Furthermore, a significant proportion of value from geospatial data will come from more widespread adoption of geospatial data products and services by firms across a large number of sectors. For example, in some instances the usage of products and services generates additional data that is fed back to the data collector. These can contribute to network effects, where the quality of the upstream supplier's offering is related to the number of user, such as when a geospatial service relies on crowdsourced data, it becomes more accurate as the user base increases (as represented by the feedback loop to "data collectors" in Figure 34).

The vast majority of interviewees said that there is potential for the geospatial data market to grow further. They gave examples of how sectors which currently use geospatial data can become more geospatially intensive (such as transport, the insurance sector, the maritime industry as well as property and construction) and how geospatial data can be put to other uses going forward (such as in the

healthcare sector). In particular, stakeholders told us that they expect growth to be driven by new data sources and greater levels of data fusion. Other stakeholders noted that future technological advances will have an important role to play in driving future usage of geospatial data. For example, we were told that further miniaturisation of satellites and associated reductions in costs could open up a wider range of use cases for space data.

The Geospatial Commission should continue to encourage greater adoption of geospatial data across the economy and facilitate the innovations that will enable this process.

4.4 Importance of facilitators

Several geospatial experts and stakeholders noted that, given the level of change which this ecosystem is currently undergoing, facilitators play a very important role in ensuring the ecosystem continues to function and develop. This type of facilitation is carried out by different organisations and occurs in different ways:

- Coordinating engagement between the core geospatial community (supply side of our ecosystem illustration) and the wider array of sectors which are increasingly becoming aware of geospatial value (demand side of our ecosystem illustration) is becoming increasingly important. Ongoing innovations will continue to open up new use cases, which will require new channels of engagement with an enlarged potential user community. We were told that, without the presence of dedicated facilitators, members of the geospatial community could, in some cases, struggle to identify the right stakeholders to approach in other sectors.
- We were also told that different organisations on the supply side of the geospatial ecosystem increasingly need to engage with each other to collaboratively develop these new innovative products and services and combine distinct forms of geospatial data together in new ways. There was a consensus that collaboration and combining geospatial data with other forms of information will be a key factor in unlocking future growth and value. Stakeholders agreed that the value of data will be maximised when individual sources of information are joined up.

5 FUNCTIONING OF THE GEOSPATIAL DATA MARKET

In this section we discuss the ten core findings of the study, which relate to economic dynamics of the market. These findings present a detailed evidence base to inform the Geospatial Commission in supporting the market to generate additional value to society.

1. **Certain emerging geospatial data segments may have relatively few suppliers and buyers (a "thin" market).** This can make price setting difficult for suppliers if they cannot benchmark against other similar service offerings. It can also limit interest from potential users who lack information about a suitable price to pay. This is observed in multiple segments. For example, mobile phone and Global Positioning System (GPS) data can provide insights into aggregated mobility patterns. However, some potential buyers of this data can lack comparative information on prices paid for similar data or services. This can make it difficult for potential buyers to assess value for money and for sellers to stimulate more demand.
2. **There are potential benefits from reuse of privately collected geospatial data that can accrue widely.** For example, this type of data can inform the development of future infrastructure by providing insights into journey patterns. This data can be collected via non-traditional mechanisms, such as crowdsourced information from a large number of connected vehicles, or data generated as a by-product of activity in other markets, such as exercise tracking applications. Therefore, greater sharing of geospatial data can generate economic and social value. However, substantial investment is needed to collect certain types of data and the potential returns can be uncertain. As a result, commercial geospatial activity can follow the pattern of intellectual property business models. Even though the cost of providing access to this form of geospatial data may be low, the collector needs to be rewarded for making the risky investment, which may result in a unique market advantage. Incentives for data sharing that encourage sharing of commercially collected data will need to be created. This is beneficial for society while still allowing those private sector data holders to recoup their investments and incentivise ongoing data collection. In other cases, the commercial sensitivity of certain types of data may mean that providers are unwilling to share it regardless of the price or incentive offered, especially if they view the recipient as a potential competitor.[104]
3. **As the geospatial data market operates as an ecosystem across a number of different industries, conclusions about competition within the private sector will vary for different parts of the ecosystem.** We were told by some market participants (such as developers of consumer-facing applications which incorporate a mapping interface) that end-user familiarity with established mapping platforms can be an important commercial advantage for some mapping providers. This may, in some cases, lead to the development of strong commercial positions amongst established mapping providers. Previous work

[104] This reluctance to share data was also noted by the CMA's (2020) conclusions as part of their online platforms and digital advertising market study.

has highlighted how the collection of location data via mapping services allows those providers to operate more effectively in other related digital markets, such as advertising.[105]

4. **Public sector organisations that provide geospatial data and services also operate across multiple areas of the geospatial data ecosystem, and there are often clear economic rationales for their involvement.** However, there is evidence that remits given to some public sector bodies may be crowding out private sector activity, for example where the public sector provides a downstream service underpinned by data which they have legitimately collected and which other organisations have difficulty accessing.
5. **Geospatial data products and services that are currently available are not always being used even when they can add value.** This is in part due to a lack of demand-side awareness of the value that geospatial data can bring. For example, we were told that, in some cases, policymakers were not incorporating available geospatial insights into their decision-making process as they were unaware of the value it could offer. In other cases, demand-side organisations are aware of the value of geospatial data but face barriers to successful implementation, such as inadequate data infrastructure or outdated IT systems.
6. **Access to finance is not consistent across all segments of the ecosystem. For example, there appears to be more competition between funders for companies at early stages of funding compared to later stages.** Our analysis of comparable sectors suggests that this is not atypical and is broadly in keeping with the pattern we see in other firms classified within related sectors, where the vast majority of fundraising occurs at earlier stages of start-up development. However, there may still be value in broadening the supply of current geospatial funding sources. The observed patterns of funding may, in part, be due to wider trends in funders joining together and forming syndicates at later stages of start-up funding rather than competing with each other.
7. **Providers are aware of their need to comply with privacy regulations in relation to geospatial data and of the ethical challenges in relation to the use of location data.** These ethical challenges apply primarily in the context of information on the movement and location of people. They need careful consideration as certain forms of geospatial data can be used to identify individuals. In other cases, geospatial data is used to highlight aggregate movement patterns. For example, information on movement patterns can be collected via mobile network data when handsets interact with mobile masts or when GPS data is harvested via mobile phone applications. As with other forms of data, market participants would welcome further clarity around whether the collection method for certain types of location data (especially GPS data harvested from mobile phone applications) requires further safeguards to prevent any risks to privacy and maintain consumer confidence. A balance needs to be struck as excessive intervention in this area could have unintended consequences such as discouraging data usage and stifling innovation. It may

[105] See for example CMA (2020): https://assets.publishing.service.gov.uk/media/5efc57ed3a6f4023d242ed56/Final_report_1_July_2020_.pdf

be that the development of a framework for the ethical usage of geospatial data could help to drive further usage.

8. **Numerous stakeholders reported that geospatial skills are becoming essential components of a wider range of skill sets, particularly data science capability, of which there is a shortage.** In particular, we were told that it is very difficult to find candidates with a combination of geospatial expertise, data science capability and non-technical/soft skills. Overcoming these shortages may require geospatial skills to be included in existing data education offerings and new data career pathways to be developed. These pathways could include dedicated geospatial apprenticeships, for example.
9. **Commercial organisations want to access public sector geospatial data via flexible and modern mechanisms that allow them to pay according to the volume of usage and only access specific data attributes of interest.** High upfront costs for buying and hosting geospatial data can be an access barrier. For example, we were told that users want to access data via machine-readable Application Programming Interfaces (APIs) that enable them to pay in line with the amount of data they use and also to hone in on specific data attributes of interest. Access to public sector data can also be limited when the organisations which have collected and hold such information are not set up or incentivised to provide commercial geospatial products. This can occur, for example, when valuable geospatial data is generated as a by-product of another administrative process such as payment of subsidies.
10. **The quality of public sector data is generally high. However, the provision of local authority data can be inconsistent across certain areas.** For example, we were told that different local authorities store data in a variety of different formats and also have their own access arrangements in place. This can increase the time and effort required to examine local data.

5.1 Thin markets in the geospatial ecosystem

Geospatial data is embedded in numerous sectors across the economy. In several instances, these use cases involve relatively few sellers and buyers. This can make price setting difficult for suppliers if they cannot benchmark against other similar service offerings, and it can limit interest from potential users who lack information about a suitable price to pay.

For example, we were told by stakeholders on both the demand and supply sides of the mobile network data segment of the ecosystem that data supply is highly concentrated amongst a small number of network operators and their intermediaries. This is primarily because such suppliers are inherited from a relatively concentrated telecoms market. Trying to enter this market as a supplier of geospatial information based on mobile network data would first require the entrant to build a significant customer base before they generate useful geospatial data. This constitutes a significant entry barrier due to the associated upfront fixed costs. However, the barriers to entering this segment for existing mobile network operators are far smaller.[106]

[106] There are also related forms of data collection which a broader range of firms offer that can in some cases serve as a substitute for mobile network data. This includes GPS data harvested from applications which

Multiple stakeholders noted that demand-side actors can be reluctant to engage with a new product or service if their ability to compare the price paid for similar data products or services is limited. This makes it difficult to assess value for money and stimulate activity when the market is relatively thin in terms of both supply and demand. Making previous data transactions more transparent across the ecosystem could help to close these informational gaps. We were told that the entry of new providers of mobile network data (existing mobile network operators who decided to develop this capability) allowed customers to make these types of comparisons more easily, which, in turn, gave them a higher degree of confidence that the products being offered were legitimate and fairly priced.

This issue of having relatively few buyers and sellers of data and related services is not confined to the mobile network data segment of the ecosystem. Firms across multiple geospatial segments told us that they were selling a service or product which was not directly comparable to other market offerings. We were told that, in this context, market "thinness" can make price setting difficult due to a lack of obvious benchmarks. This is in keeping with existing evidence from the Bennett Institute for Public Policy (2020) which says: "*most markets for data are not thick markets, which means they do not have enough buyers and sellers to converge on a market price that reflects the true economic value of data*".[107]

Some supply-side stakeholders reported that they examine the price of more traditional information sources that they are trying to replace when pricing their own service. For example, a firm that offers services based on earth observation data to clients in the financial services sector may examine the price of other information streams, such as earnings reports, that their clients may also demand in order to assess willingness to pay.

The Geospatial Commission could consider options to increase transparency regarding pricing and offerings available in certain market segments. For example, the Geospatial Commission could help to share learnings associated with using this type of information across the public sector or, in some cases, facilitate greater linkages between demand- and supply-side organisations.

5.2 Data sharing across the geospatial ecosystem

Greater sharing of privately collected geospatial data could generate social benefits in the future

In its recently published strategy, the Geospatial Commission stated that it will take "*an active and considered role in identifying the high value opportunities and corresponding barriers and incentives to enable more private sector data to be*

have relatively lower barriers to entry because firms do not have to build or pay for the network infrastructure that mobile network operators use to harvest mobile phone data. Some stakeholders told us that GPS data had become less common in the UK in the last two years following the advent of GDPR. This package of regulations meant that developers were required to explicitly ask for users' consent to track location.

107 https://www.bennettinstitute.cam.ac.uk/research/research-projects/valuing-data/

shared to drive economic growth and improve services to citizens and consumers" (Geospatial Commission, 2020).[108]

Greater sharing of geospatial data can generate economic and social value. However, commercial geospatial activity often follows the pattern of intellectual property business models. Specifically, collection of geospatial data may involve high upfront costs and, once the data has been collected, may give the organisations that hold such information a unique market advantage meaning that providers may be unwilling to share it, especially in cases where they view the recipient as a potential competitor[109]. As a result, there are significant barriers to data sharing even if the marginal cost of providing data is relatively low.

It is important to note that different commercial organisations have made different levels of investments in data collection and have varying business models. As a result, some private sector data holders told us that they are happy to provide this information for free to users who can generate some public good. This may apply when the data is not going to be a primary source of revenue for the data owner. In these instances, the Commission may simply need to publicise the data that is already publicly available.

In other cases, as we describe above, where the data is expensive to collect or offers significant commercial advantages, the data owner has different commercial motivations. The cost of providing access to this form of geospatial data may be low, but the collector needs to be rewarded for making the risky investment, which may result in a unique market advantage

The insights from sharing newer types of geospatial data can benefit the wider economy. For example, the data collected from vehicle sensors can be used to survey road assets for infrastructure providers. These assessments can detect specific changes such as cracks in the road surface. We were told that identifying this early on may make it possible to reduce maintenance costs. In addition, the same information can be used to highlight near-misses in terms of potential accidents, which is clearly of value to urban planners. Likewise, aggregated and anonymised patterns of individual activity data collected by applications could be shared with policymakers. This could aid the development of safe and accessible infrastructure by enabling an examination of cyclist routes that are most likely to be used, for example.

Due to the observed barriers, incentives for data sharing will need to be created to encourage companies to share commercially collected data that is beneficial for society, while still allowing those companies to recoup their investments. ***The Commission should consider mechanisms which facilitate greater levels of data sharing by taking account of the commercial motivations of data owners.***

In addition, we were told that, in some cases, a range of mutually beneficial data-sharing partnerships could be put in place (which may involve commercial organisations sharing information with each other as well as sharing data with the

[108] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/894755/Geospatial_Strategy.pdf p. 43

[109] This reluctance to share data was also noted by the CMA's (2020) conclusions as part of their online platforms and digital advertising market study.

public sector). For example, multiple competing autonomous vehicle (AV) organisations could benefit from sharing safety data. However, we were told that currently there can be a lack of compelling reasons to share data. This may be because the value of engaging in a data exchange is often not clear to both parties as new forms of data do not always have universally agreed values.

Geospatial Commission input may also be useful in some of these examples. For example, the Geospatial Commission has led to development of the National Underground Asset Register (NUAR) programme (which involves creating a digital map of underground pipes and cables to reduce disruption and increase safety). Some degree of public sector coordination was necessary in this case because high levels of private sector participation in the scheme were needed to ensure significant value was created (Geospatial Commission, 2020).[110]

5.3 Competition in the geospatial data ecosystem

Competition operates differently in different parts of the ecosystem. Most notably, there is likely to be upstream competition and downstream competition.

- Upstream competition occurs when commercial users of geospatial data or intermediaries choose between rival suppliers of geospatial information.
- Downstream competition occurs when final consumers make choices in retail markets for products and services that incorporate geospatial insights.

Market position of large commercial geospatial firms

Multiple commercial interviewees emphasised the strong market position of large digital organisations in certain segments (such as consumer-facing applications that incorporate a mapping interface). The firms that expressed these views also purchase geospatial inputs from large suppliers, which providers us perspectives from the demand-side. However, they also have their own product or service offering underpinned by geospatial data which is subsequently marketed at individual users or other commercial customers.

In these parts of the geospatial ecosystem, several firms we engaged with told us that they purchase a bundle of services from large technology firms, allowing them to integrate their own products, services or platforms with e.g. mapping services.

We were told by platform developers who use these bundles of services that the quality of the offering is generally high and meets their needs as a developer adequately. In particular, the services they purchased contain all the requisite features and are designed to be integrated into other applications.

Some stakeholders did note that some providers had increased prices significantly over the last two years without a lot of warning. We were told that prices are now considered to be quite high, which, in some cases, could act as a barrier to entry for app developers. Some stakeholders reported that further price rises could mean that existing business models could no longer operate effectively while utilising those services.

110 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/894755/Geospatial_Strategy.pdf

In some instances, the increases in price had led to users seeking alternatives which are cheaper or open source. These may be sourced from other commercial mapping providers or open source alternatives. Some stakeholders felt that these offerings were close substitutes for existing commercial offerings.

We were told that one of the key advantages enjoyed by large mapping providers is that the final users of the application who the developers are trying to attract and retain are already familiar with certain and specific interfaces. This makes some solution providers reluctant to switch away as having a well-known mapping platform included within your app may add an element of credibility to your product or service offering.

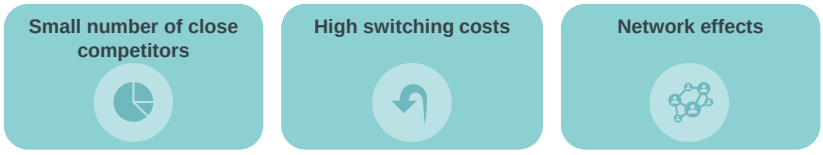
In these cases, there are links between this geospatial activity and other digital market segments. For example, previous work (CMA, 2020) has highlighted how the collection of location data via mapping services and consumer platforms allows certain providers to operate more effectively in other related digital markets, such as advertising.

However, the advantages described above do not apply across the board. We were told that some applications may prefer to use different suppliers. For example, it may be that certain mapping services specialise in off-road features, which mean they are tailored for use by pedestrians. This makes these offerings more attractive for certain app developers.

More generally, we can draw out implications from this example in other geospatial contexts. Private sector firms are likely to have strong commercial positions in business-to-business geospatial market segments that display a number of characteristics (Figure 39). Previous work has highlighted how the collection of location data via mapping services allows those providers to operate more effectively in other related digital markets, such as advertising.[111]

These segments typically have a small number of upstream providers offering comparable goods or services. Also, there may be entry barriers, such as large capital costs, which further limits user choice.

Figure 39 Scenarios where upstream geospatial providers may have a strong commercial position



Source: Frontier

There may also be switching costs. For example, an application developer may not want their app's final user-facing appearance to change. As a result, they have an incentive to remain with their current geospatial supplier even if the associated costs have risen.

Finally, there may be network effects such that the quality of the upstream supplier's offering is related to the number of users. This increases the likelihood

[111] See for example CMA (2020): https://assets.publishing.service.gov.uk/media/5efc57ed3a6f4023d242ed56/Final_report_1_July_2020_.pdf

of a single offering emerging which other providers struggle to compete with. This could occur, for example, when a geospatial service relies on crowdsourced data and is therefore more accurate as the user base increases.

Competition in public sector geospatial activity

Some upstream geospatial activity such as data collection is carried out by public sector organisations, including the Geospatial Commission's six partner bodies. Public sector bodies operating in the geospatial market are sometimes the primary undertakers of certain data collection or production activities, which are often specified in statute or their "public task".[112]

While we cannot be certain what would have happened in the absence of the specific public task functions these bodies have been designated to carry out, in certain cases, some form of government intervention is needed to collect universal and granular geospatial data. This may be because there are high fixed costs associated with this type of data collection, as well as a lack of private sector use cases which require nationwide, granular and universal coverage. Private sector interviewees generally felt that public support for nationally comprehensive core geospatial goods is beneficial for the sector as a whole.

We were told that, in some cases, the partner bodies and devolved administrations provide a national framework within which private sector companies can contextualise their offerings. This generates benefits for each of these private sector organisations, but these benefits are widely dispersed amongst these organisations, which means that no single commercial organisation would provide and update this framework without some form of public involvement. This public involvement could take a number of forms to carry out this activity, ranging from establishing national agencies to funding of private sector organisations.

In some of these cases, where public bodies are the only collectors of certain types of data, these public organisations have also moved to the right-hand side of the value chain and are producing products and services tied to that data. We were told by some commercial organisations that some of these downstream public sector data services are not subject to any direct competition as the underlying data has not been opened up fairly to potential competitors.

For example, some organisations reported that public sector geospatial asset holders do not provide flexible and scalable pricing or standardised licensing for their underlying data. In addition, stakeholders felt that, in some cases, there was a lack of transparency in terms of what data was available for commercial use. This implies that existing products offered by public bodies which rely on this inaccessible underlying data cannot be competed with.

Even if some demand exists for the final products that are based on this publicly collected data, it still may not be feasible for private sector organisations to collect

[112] The term "public task" is an important concept in the "Re-use of Public Sector Information Regulations 2015" (the 2015 Regulations). It specifies the core role and functions of public sector bodies in relation to the information they produce, collect or hold, which may be statutory or established through custom and practice. See: https://www.nationalarchives.gov.uk/information-management/re-using-public-sector-information/about-psi/public-task/

comparable underlying data due to the upfront costs involved and uncertainty regarding the magnitude of future demand.

It was acknowledged that some of these barriers may be justified by the need to protect commercial intellectual property (IP)[113] or to comply with General Data Protection Regulation (GDPR).[114] We were also told that some public bodies do not have the capacity to deal with all data requests in a timely manner.

The UK's Geospatial Strategy includes an action to develop a set of harmonised licences for the use of public sector location data. From our qualitative engagement, it seems that this would be welcomed by a number of market participants. However, care will be needed in some cases to ensure that ongoing public sector data collection and curation is not undermined by changes in commercial revenue. Also, private sector stakeholders told us that any major change to how public sector data is licensed needs to be carefully considered, as it can require other organisations to make significant changes of their own.

Some stakeholders told us that certain public bodies had made good progress recently in this regard and that pricing structures had been simplified, which reduced entry barriers (see text box below). However, in other cases, pricing uncertainty or unwillingness to provide underlying data remained as issues.

CONVEYANCING REPORTS

The Coal Authority uses its data to create coal mining reports for conveyancing purposes (CON29M reports). These reports are used when buying and selling domestic properties in areas with previous coal mining activity. They provide information on possible risks to land and property using geospatial data.

Prior to 2015, the Coal Authority was the only organisation that could provide these reports as the copyright for the specific form was owned by the Law Society. In recent years, the Law Society has permitted other commercial organisations to provide these reports by buying underlying data from the Coal Authority. This has led to an instant increase in contestability and increased consumer choice. The Law Society's (2019) own guidance stated that it took this decision as it wanted "*to encourage a competitive market in coal mining reports*".[115]

The specifics of this example, such as the precise form of geospatial data in question and the original copyright restrictions, will not be directly relevant to other market segments. However, it is still worth considering whether the goal to increase choice and competition via an external policy change could be applied elsewhere using an alternative mechanism.

Possible crowding out of private sector activity

Some market participants (in segments where private and public sector organisations compete in selling goods and services to other organisations)

[113] Where partner bodies hold data on behalf of commercial organisations.

[114] Where partner bodies hold data that contains personal information.

[115] https://www.lawsociety.org.uk/topics/property/con29-forms

expressed a view that they were unable to effectively compete with public sector organisations in certain market segments. This usually occurred when private sector organisations felt that public bodies were focusing on generating commercial returns via the provision of commercial solutions and were carrying out services on the right-hand side of the value chain. All stakeholders reported that this sort of activity was in line with the current remits given to these public sector organisations by policymakers.

Stakeholders described specific products that partner bodies brought to market in direct competition with existing private sector offerings. This may have led to private sector firms choosing to exit specific market segments. This market exit could be because competitive forces are working properly and the public sector offering is genuinely more effective. Or it could be because the public sector provider has certain inherent advantages which relate to its receipt of public funding. We were told that, in some cases, private sector firms may be refraining from investing in developing new solutions as they are worried that public providers might copy them if they turn out to be successful.

Other stakeholders reported that there is currently a lack of clarity regarding the public sector's role in this context and that it can be uncomfortable to compete with a public body in one market segment and rely on the same public body for input data in another segment. We were told that private sector organisations are unsure whether the public sector is there to release data which benefits the entire sector or to build their own rival applications.

Multiple stakeholders also emphasised that there are advantages in maintaining public sector organisations' direct competition with private sector organisations. Specifically, stakeholders reported that this allows public bodies to keep their core services up to date and innovative. Stakeholders acknowledged that responding to market signals keeps public bodies agile. This may not be the case if their strategy was determined internally. In addition, several partner bodies and devolved administrations generate revenue from products and solutions that compete with the private sector. This revenue helps to reduce or offset the required taxpayer investment.

Some stakeholders suggested that public bodies that are active in these segments should continue to adopt a partner first approach wherever possible to avoid crowding out existing activity. We were told that, if this was implemented more often, public sector bodies could maintain a presence at the cutting edge and generate revenue without disadvantaging existing market participants.

The Commission should consider clarifying the future role of public sector geospatial organisations and explaining why certain organisations fulfil specific roles across the spectrum of the value chain.

Other interactions between public sector organisations and private companies across the value chain

As well as the direct competition between public and private sector organisations described above, in some cases, private sector organisations extract, package, integrate and build services using information that has been collected by public or semi-public bodies to produce a final good. In some cases, this data has been

deliberately produced by the public sector for this purpose; in other cases, the input data is actually a by-product of other value-adding activities.

For example, several private sector organisations which carry out economic activity and drive growth in a number of sectors described how their activity was based on foundational geospatial assets such as Ordnance Survey's MasterMap. ***The Geospatial Commission should consider how to best identify the UK's core geospatial assets, many of which are currently being collected by public sector organisations. The Geospatial Commission could then consider how their value can be maximised.***

The recently announced Public Sector Geospatial Agreement (PSGA)[116] may help in this regard by improving access to Ordnance Survey's core data for start-ups, businesses and innovators.[117] Given the timing of our fieldwork, we were unable to directly assess the impact of this policy to date.

In other cases, public sector organisations are consumers of geospatial products which are offered by a range of private sector organisations. This includes usage of data products and services that the public sector cannot or does not choose to collect. For example, we were told that public bodies such as local authorities currently rely on private sector firms to carry out bespoke aerial photography work, which underpins public service provision.

As well as supplier-to-customer linkages, there are also situations when public and private sector organisations collaborate to co-develop solutions:

- A number of the partner bodies and devolved administrations we spoke to described how they are currently collaborating with commercial organisations. Partner bodies considered these partnerships to be valuable because commercial organisations could act as intermediaries and open up new commercial markets by overcoming informational gaps. This, in turn, can lead to increased use of public sector data. The commercial intermediaries achieve this by leveraging existing relationships or including public sector data within established platforms that act like a "shop window". Simply making data available may not be sufficient, therefore, to guarantee widespread usage. Public sector organisations may not always have the capacity or expertise to promote products in multiple industries themselves and also foster the required levels of demand-side awareness that would maximise the number of potential users.
- In other cases, private sector organisations actively augment the partner body's geospatial expertise with their own sector-specific information. We were told that this type of activity adds value and can lead to a more attractive or holistic product which is tailored to use cases in a certain industry. For example, this could include a public body partnering with a private sector organisation to combine accurate digital mapping services with satellite imagery to examine air quality or facilitate asset management.

Certain partner bodies noted that they would like to carry out more of this activity but sometimes struggle to identify the right organisation to partner with. ***This***

[116] https://www.ordnancesurvey.co.uk/business-government/public-sector-geospatial-agreement

[117] https://www.gov.uk/government/news/government-announces-new-10-year-public-sector-geospatial-agreement-with-ordnance-survey

suggests that the Geospatial Commission could consider mechanisms to encourage further mutually beneficial linkages between public and private geospatial organisations. These would support the development of solutions underpinned by data that the private sector could not feasibly collect on a consistent basis.

5.4 Awareness of the value of geospatial data

In some cases, there may be awareness issues related to the value of geospatial data

Several supply-side stakeholders from the private and public sectors described a lack of awareness about geospatial data in both sectors. There is widespread acceptance that this informational issue may be holding back greater future adoption of geospatial data.

Partner bodies highlighted the public sector's lack of awareness. Specifically, they told us that there is a knowledge gap relating to how geospatial insights could be used in workflows. In particular, their view was that some civil servants and people in senior leadership positions did not always recognise that geospatial data can be of assistance and provide higher-quality insights than anecdotal or out-of-date alternative evidence sources. As a result, stakeholders said that, in some cases, the public sector's overall adoption of geospatial data has been relatively slow.

On the demand side, we were told that commercial private sector organisations in specific sectors may not be aware that they have a problem that can be solved by geospatial data. In addition, once they engage with the market they often do not know where to go to. In many cases, they are bombarded by multiple providers and it may be difficult to determine a high-quality offering before engaging. As we described above, the Geospatial Commission could consider publicising different use cases to help with this issue.

A lack of awareness of new and emerging geospatial data sources may also be affecting public sector procurement

In some cases, we were told by commercial stakeholders that some public sector customers were reluctant to transition away from traditional data sources and engage with newer forms of information even if they could provide more insights or nuanced answers. This may be due to a lack of awareness of the potential value of new and emerging sources of information and their associated benefits.

In addition, some organisations which hold these emerging forms of geospatial data told us that procurement processes can, in some cases, make it difficult to work with government bodies. Stakeholders told us that current demand for different types of geospatial data across the public sector is very decentralised and could benefit from coordination. Specifically, we were told that multiple departments and public bodies may want access to similar data services. However, they are rarely joined up, which makes the landscape difficult to navigate for suppliers. This also means that it is harder to embed geospatial thinking in a consistent way across government. In addition, the current system may result in some degree of wasteful duplication.

The Geospatial Commission should continue to empower public sector users to use these new forms of geospatial data where relevant and possibly take on a coordinating role across government. There may be value in carrying out work in the future to better define government data needs across multiple departments and organisations. The Geospatial Commission has committed to rationalising the public sector's procurement of Earth Observation data, for example (Geospatial Commission, 2020).[118]

The Geospatial Commission may have a role to play in closing these awareness gaps

The Geospatial Commission could consider options to increase awareness. Multiple stakeholders felt that the Geospatial Commission could play a useful role in continuing to educate people about the value of geospatial data. For example, it was suggested that the Geospatial Commission could elevate the influence of geospatial data in the senior leadership of government. Specifically, we were told that the Geospatial Commission could articulate where geospatial considerations are important or where geospatial insights could improve existing analysis. This could include incorporating references to geospatial data within current policy frameworks such as HM Treasury's Green Book, which sets out best practice for appraisal and evaluation in central government (HM Treasury, 2018 A).[119]

Other stakeholders also noted that the Geospatial Commission should consider uncovering and communicating specific value realisation scenarios. These would give successful examples of public and private sector geospatial usage. Other organisations could learn from these success stories and realise how existing assets can be used.

5.5 Access to finance in the geospatial ecosystem

We also explored the topic of finance within the geospatial ecosystem. Organisations noted that specific market segments such as the development of space-based technology are very attractive for funders. This is because of the emergence of innovative business models that have the potential to transform society. Funders can clearly see the potential for high rates of return and are keen to invest.

Start-ups agreed that the availability of funding depends on the specific market segment in which they are based. For example, firms noted that there has recently been a lot of capital available for emerging InsurTechs and Proptech firms, as established players have realised the value they can bring.

This may not be the case across the board, however. We were told that there is a long lead time before investments in certain areas (like specialised hardware required for data collection) pay off. As a result, funders can be reluctant to engage

[118] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/894755/Geospatial_Strategy.pdf

[119] https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent

and may focus their resources at other stages of the value chain. This may reflect an imperfection in credit markets.

More generally, stakeholders reported that there may be more funders providing finance to very early-stage geospatial firms and comparatively fewer funders at later stages. This could be in part due to a trend of syndication whereby multiple funds collaborate before investing in a larger more-established firm. In addition, the lower rates of funding at later stages could in part reflect the fact that some geospatial firms do not generate sufficiently high returns relative to other potential investments.

Our quantitative market identification work showed that over 83% of equity funding given to geospatial companies identified on Beauhurst were at the earlier "seed" and "venture" stages[120], compared to 17% receiving funding at the "growth" and "established" stages (see Section 3 for further details). This is broadly in keeping with the pattern we see in other firms that Beauhurst has classified within related sectors or themes. For example, 80% of equity funding given to "adtech" companies identified on Beauhurst was also at the earlier stages. The equivalent figure for "proptech" firms was 88%. This suggests that, if there is a shortage of later-stage funding, it is not limited to the geospatial ecosystem but applies more widely. ***The Commission should consider mechanisms to continue educating investors about opportunities in this area and raising awareness***.

Several stakeholders did also acknowledge that the future funding landscape is very uncertain due to COVID-19.

5.6 Geospatial data ethics and privacy

Data privacy is an important consideration in certain segments

Data ethics in relation to individual privacy is a relevant consideration in relation to certain geospatial data types. This applies primarily to information on the movement and location of people. Certain forms of geospatial data can be used to identify individuals. In other cases, geospatial data is used to highlight aggregate movement patterns. In our interviews, this topic was most often raised in relation to the collection of mobile network data and related forms of movement tracking.

Every stakeholder we engaged with in this context emphasised the importance of respecting an individuals' privacy. For example, in all cases, providers told us that all data that is shared is anonymised and aggregated and that all products are fully GDPR compliant. Specific providers noted that studies had been undertaken to ensure that the data cannot be reverse engineered. Other interviewees told us how they voluntarily go beyond minimum thresholds in terms of reporting aggregate movements for a set number of users

[120] On the Beauhurst platform, a company's stage of evolution is categorised as one of the following – "seed", "venture", "growth", "established", "exited", "zombie" and "dead". "Seed" and "venture" are the early stages of company start-up. These companies have existed for a relatively short amount of time. "Established" firms are those companies that have existed for significantly longer and are more likely to receive funding from private equity firms, banks and major international funds.

Several stakeholders emphasised that mobile network data is useful precisely because it shows aggregate movements rather than individual trips. Single journeys would obviously be more problematic from a privacy point of view but are also generally less helpful. For example, mobile network data is used by transport authorities to forecast demand across a region and by marketing firms which are trying to understand the effectiveness of a mass media campaign where the insights come from targeted aggregation. In these cases, the relevant insights come from aggregate movements.

> We are only interested in aggregated movements of people. Individual trips are of no value
>
> *Geospatial data ecosystem participant.*

There were, however, mixed views in terms of how privacy concerns are influencing demand. Several organisations that produce this data or sell derived products told us that clients did not frequently express privacy worries. Specifically, they felt that this type of information has become more commonly used and accepted in certain industries.

Other supply-side organisations noted that they are cautious about publicly promoting their own capability in this area. This is because they are worried about public perception. This might reduce demand across the sector more widely and contribute to a lack of demand-side awareness. In addition, we were told that some new customers still do ask a lot of questions about privacy and in some cases refuse to buy a product even if assurances have been given that everything is fully compliant. This may be because the data is less commonly used in certain sectors. Some of these concerns may stem from a lack of understanding about what mobile network data represents.

Previous work on this area noted that there are misunderstandings across the industry in terms of what mobile network data represents and what data can be legally obtained (Transport Systems Catapult, 2016).[121] A public sector demand-side organisation reported that it invested a lot of time working with its own legal team prior to purchasing an offering based on mobile network data. This was because it wanted to ensure all regulations were respected.

Multiple stakeholders told us that different forms of movement data collection should be considered differently as they have distinct characteristics and possibly different privacy implications. However, existing guidance does not differentiate between different forms of location data at a sufficiently granular level, which has left some degree of ambiguity in the market. For example, the privacy issues that arise in relation to geospatial data derived from apps which collect location data via GPS may be different to those relating to mobile network data.

Multiple stakeholders emphasised that mobile network operators are fully aware of the potential for reputational damage if they violate their customers' trust. This provides a very strong incentive to act ethically as these services account for a

[121] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/662948/utilising-mobile-network-data.pdf

small share of overall revenues but could have proportionately large reputational impact.

It may be that policy action in this context could drive further usage of geospatial data by overcoming misconceptions relating to privacy and increasing user confidence. However, a balance needs to be struck, as excessive intervention in this area could discourage data usage and stifle innovation. The Commission should work with stakeholders to remove any ambiguity over what products or services are compliant with existing data privacy regulations, and help public sector organisations to confidently purchase these services. In the UK's Geospatial Strategy, the Geospatial Commission has committed to providing guidance on how to unlock value from sensitive location data while mitigating security, ethical and privacy risks. It may be that the development of a framework for the ethical usage of geospatial data could help to boost demand in some cases.

5.7 Availability of skills

Many stakeholders emphasised that data science skills are increasingly important and hard to find

The Geospatial Commission's recent UK Geospatial Strategy (2020) includes a mission to enhance geospatial capabilities, skills and awareness. Specifically, the Geospatial Commission set out an objective to develop more people with the right skills and tools to use location data across organisations and sectors to meet the UK's needs.

In general, participants noted that geospatial skills are becoming essential components of a wider range of skill sets such as data science, as geospatial data is expanding into non-traditional sectors.

Interviewees across both the public and private sectors highlighted a potential skills shortage in relation to data science capability. We were told that in some cases the balance of required expertise within organisations is shifting. Specifically, traditional geospatial practitioner skills (such as cartography) are becoming less important in isolation and increasingly need to be used in conjunction with specialist data skills. These include data storage, programming as well as data analytics and machine learning. Multiple interviewees reported that it is very difficult to find data scientists and that they command high wages as a result.

This is in keeping with research carried out by The Royal Society[122] (2019) which concluded that data scientists are in high demand as the volume of data collected across society rises rapidly.

Stakeholders raised a number of specific issues within this theme:

- Firstly, we were told that "mature" data science skills and senior talent in this area is in particularly short supply. Organisations often struggle to find and retain individuals who have the ability to program and work with data at a high

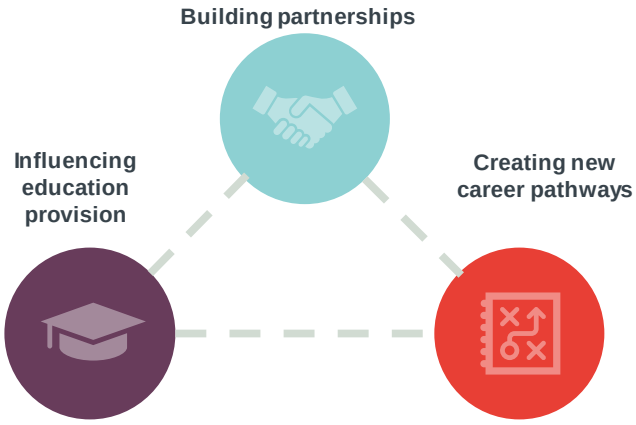
[122] https://royalsociety.org/-/media/policy/projects/dynamics-of-data-science/dynamics-of-data-science-skills-report.pdf

level and who are able to manage others and interact with customers. Other stakeholders agreed that technical skills are most valuable when combined with other capabilities like project management. This is in keeping with work carried out by Burning Glass (2019) on the demand for digital skills in the UK. They concluded that job seekers need a complete package of digital and non-digital skills for success in the economy.

- As we highlighted above, geospatial data is now embedded widely across the economy. This means that organisations are seeking individuals with a mix of geospatial skills, data science ability and sectoral expertise. We were told that finding individuals with all these elements is difficult. This can lead to organisations hiring multiple people with complimentary skillsets or making compromises.

Several possible explanations for this skill gap were put forward. Some stakeholders noted that the presence of large international digital organisations which can afford to pay high salaries makes it harder for everyone else. Other interviewees felt that the supply of labour market entrants was not adequate. A number of potential solutions were suggested (see Figure).

Figure 39 Suggested options for overcoming geospatial skills shortages



Source: Frontier

Multiple stakeholders felt that greater collaboration across the industry could help overcome certain skills shortages. For example, some public sector bodies highlighted the value of secondments. We were told that this type of movement helps staff acquire different perspectives. Other public sector organisations told us that individuals often need to receive extensive data training when they join an organisation and there would be value in centralising this material across government. This coordination would help ensure a high standard of training and a greater level of consistency. In addition, some organisations suggested that public bodies should explore the possibility of working with private companies to overcome the challenges we described above. Specifically, it may be possible to develop partnership models. For example, private sector organisations could contribute to meeting the costs of talented individuals working in the public sector. The private sector company could then receive a benefit in return, such as priority access to public sector data.

We were told that the UK is home to some of the best institutions for studying data science in the world. Some stakeholders felt that it would be helpful if additional

geospatial content could be added to a wider range of university degree courses. This could apply to a range of subject areas such as statistics. Some stakeholders told us that existing curricula are not always reflective of rapidly evolving labour markets. Including relevant geospatial elements in courses could generate interest in the topic and increase the capability of those entering the workforce. Multiple organisations think that the Geospatial Commission could have a role in "geo-enabling individuals coming out of university". Other stakeholders felt that bigger changes were needed earlier in the education system to boost interest in science and technology from an early age.

Given existing skills shortages, some stakeholders noted that it may be beneficial to create new routes into geospatial roles. For example, we were told that there is currently no dedicated geospatial apprenticeship standard. Trailblazing this standard could help to ease the supply shortages noted. The Geospatial Commission has also identified a need for better geospatial apprenticeships and has committed to establishing these routes by 2021.

In addition to data science shortages, some stakeholders raised issues which relate to specific segments of the market. For example, some stakeholders told us that earth science skills are increasingly hard to find. This may be partially due to the perception that this market segment is stagnant. Other participants told us that specialist surveyors are also in short supply, which can act as a barrier to expansion for some firms.

The Geospatial Commission could consider mechanisms to incorporate geospatial skills into the wider data science skill conversations. Potential policy options that we have described for geospatial skills (in particular those which include more fundamental changes to early years education) have parallel solutions in relation to data science skills.

5.8 Geospatial data access

We were told by multiple start-ups as well as by more-established data users that they want to pay for data on a per-use basis and access data via API calls. Start-ups' business models and product ranges are constantly evolving. This means that their demand for geospatial data streams may also change quickly and they want to experiment with new data sources before committing to a substantial investment. This is partially because geospatial data can be an experience good whereby characteristics such as quality and usefulness are difficult to determine in advance, prior to usage. Therefore, any data that they use should ideally be licensed on a flexible basis. We were told that the end users' preferred method of accessing data in this context is via API calls.

> We want to be able to move quickly and follow new sources of demand.

> We do not want to have to maintain geospatial datasets ourselves.
>
> *Geospatial data ecosystem participant*

Fixed price points which do not vary with usage may not work for end users. We were told that this is because they may have very low levels of usage initially. As a result, they would struggle to justify a significant data fixed cost. Instead, we were told that they would like to pay per API call. This allows them to determine whether they could develop a solution using the data. Fixed initial data costs were viewed as a barrier to entry.

Public bodies are aware of these trends and different access models are in place to overcome these barriers. Some partner bodies told us that one of their aims is to make their information available via APIs in the near future. They are aware of potential demand from start-ups that they currently cannot serve. In addition, the recently agreed Public Sector Geospatial Agreement (PSGA),[123] which sets out how Ordnance Survey data is made available to developers, includes three new APIs and a greater focus on individual data component access. Certain stakeholders did tell us that they have had positive experiences using public sector APIs to access geospatial data. Specifically, flexible pricing models have enabled them to develop business models that would not have been possible if they were required to pay for the full dataset up front.

The Geospatial Commission should continue to ensure that the public sector supports SMEs by providing access to public sector geospatial data on a more granular basis which acknowledges the inherent uncertainty and flexibility of emerging business models.

These granular and flexible pricing models do not have to come directly from public sector bodies. They could be facilitated by private sector resellers of public sector geospatial data. These intermediary organisations purchase large volumes of information from partner bodies, repackage it and sell it on to end users.

Data that could add value in the future needs to be accessible

Several stakeholders told us that they have encountered issues when trying to access data from public sector bodies which hold vast amounts of geospatial data but are not incentivised or set up to provide their data commercially. These organisations hold potentially valuable geospatial data which they capture for their own purposes related to their core activity. However, they are not set up to provide commercial geospatial products and may not always have an incentive or interest in considering the needs of end data users. As a result, demand-side stakeholders noted that interactions with them were sometimes slow and that accessing the data of interest on reasonable terms was hard. This issue applies to a range of different types of data and is not restricted specifically to geospatial data.

Encouraging these data owners to manage their data in a way that makes it useful for others may involve the Geospatial Commission providing information about the value of doing so and, where necessary, providing

[123] https://www.ordnancesurvey.co.uk/business-government/public-sector-geospatial-agreement

funding if transitioning towards this type of attitude and data stewardship involves a financial cost.

Other stakeholders reported that some public bodies hold "protectionist" attitudes to their data. This is possibly because of a desire to be seen as a single authoritative source on a particular topic. This can limit the extent to which source information is shared.

In other examples, new use cases are emerging. This is generating new data needs that previously did not exist. For example, the development of types of high definition maps for autonomous driving may, in some cases, benefit from greater public sector "input data" sharing. This could specifically relate to road furniture information or traffic light signals, for example. Clearly, a balance will need to be reached as it will not always be feasible for the public sector to centralise and provide all geospatial data that will be of potential use to every sector. Deciding whether to make this data available will involve trading off several factors. This will include the potential value that will be unlocked, the cost of gathering and maintaining that data and the possibility of private sector collection and provision of equivalent or proxy information.

5.9 Geospatial data quality

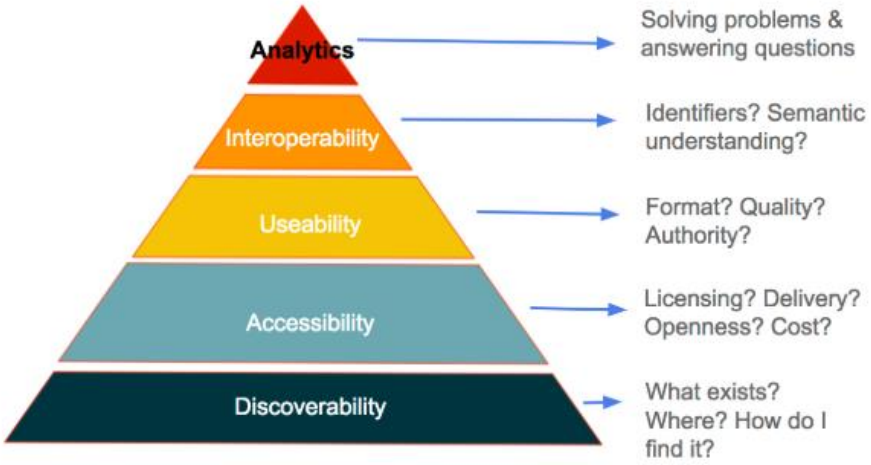
The Geospatial Commission's Data Standards Team previously highlighted that data needs to be:[124]

- discoverable so that potential users know what exists and where to look;
- accessible once users find the data;
- useable in terms of its quality and format; and
- interoperable so that users can join it to other data sources to generate additional value.

Once these conditions are filled, users can start to carry out analysis and generate new insights (see Figure below).

[124] https://geospatialcommission.blog.gov.uk/2020/01/27/getting-the-most-from-our-national-location-data/

Figure 40 Hierarchy of data needs



Source: *Geospatial Commission* https://geospatialcommission.blog.gov.uk/2020/01/27/getting-the-most-from-our-national-location-data/

Multiple organisations said that the general quality of public sector geospatial data in the UK is very high. We were told that specific products, such as OS's MasterMap, produced by national agencies or public bodies are thought of as world class.

Local authority data

Organisations in both the public and private sectors told us that they encounter geospatial data quality issues when interacting with local authorities. Some partner bodies that rely on input data generated by local authorities highlighted a lack of consistency across different local government organisations. This led to inefficiencies and increased the amount of time partner bodies need to invest in cleaning and processing data. We were told that this is partially because each local authority operates in a slightly different way. Specifically, they may have different resources, capabilities and legacy systems which act as a barrier to standardisation at other stages in the value chain. We were told that regional agencies which use local authority planning data struggle with the fact that different local organisations adopt varying data definitions and record elements differently.

In keeping with the experiences of public bodies, several companies raised the issue of the consistency and accessibility of local authority data. Specifically, we were told that valuable datasets are not digitised in certain areas and in some cases physical access may be artificially restricted. Stakeholders felt that the cost of maintaining accurate data can be high and a lack of investment may explain the apparent variation. Stakeholders told us that there has been persistent underinvestment in geospatial resources in local government. We were told that specific private sector organisations have developed business models that overcome these issues. Some firms specialise in digitising data held by local authorities that would otherwise be very time consuming to access. The need to make such investments in upfront processing could act as a barrier to new entrants.

The Geospatial Commission could consider the benefits associated with further investments in local authority geospatial capacity in terms of both human and physical capital.

Interoperability

Interoperability of data was raised by several different stakeholders in a variety of contexts. The Digital Land Review[125] recommended enforcing common standards and identifiers. Also, the Geospatial Commission included a commitment within the UK Geospatial Strategy to focus on improving interoperability of new and existing location data in key government priority areas. We were told that some good progress has been made in this area already (see text box below).

UNIQUE PROPERTY REFERENCE NUMBERS

Stakeholders felt that the introduction and adoption of Unique Property Reference Numbers (UPRNs)[126] was a good example of a successful Commission initiative. UPRNs provide a comprehensive, complete and consistent identifier throughout a property's life cycle. We were told that there was previously a void in this area. There was a clear need to make addressing data more consistent across different geospatial datasets. Stakeholders reported that the Geospatial Commission helped to coordinate and provide a standard to use across government. This has increased interoperability considerably.

Stakeholders also described how the public sector response to the COVID-19 crisis has increased the importance of interoperability and has highlighted new use cases which require linking different spatial datasets (for example, identifying vulnerable individuals who needed additional support meant that addressing data across multiple departments had to be integrated).

Some private sector data users noted that existing government platforms can sometimes seem like a "data landfill". This is because they contain information in a variety of formats. As a result, the platforms are difficult to navigate and finding interoperable data is a challenge. We were told that it would be helpful if as much data as possible was consolidated into a legible and machine-readable format.

Other public sector stakeholders described how they are currently implementing programmes to increase interoperability across multiple different geospatial data domains to create efficiencies. However, they emphasised the challenge in getting a new system like this off the ground as multiple government departments need to buy in to any proposals.

Crowdsourced geospatial data is increasingly important

Several stakeholders noted that their geospatial data collection relies partially or fully on crowdsourced data. For example, we engaged with app developers whose customers share information with the wider user community on journey patterns or activities. Similar points were raised by stakeholders in the autonomous vehicle

[125] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/733864/Initial_Analysis_of_the_Potential_Geospatial_Economic_Opportunity.pdf

[126] https://www.ordnancesurvey.co.uk/business-government/tools-support/uprn

sector. Providers operating in this space use data harvested from vehicles with in-built sensors to create or update high definition (HD) maps.

Specifically, we were told that anonymised and aggregated data gathered by in-car sensors is uploaded to a cloud platform. This information can then be used by autonomous vehicles to contextualise where they are and act as a redundancy for the sensor technology. Future innovations and new technologies

We were told by multiple stakeholders that geospatial data collection, processing and analysis is continuing to evolve at pace. In particular, multiple interviewees from both the private and public sector highlighted how 3D geospatial data collection may have a more important role to play in the future.

For example, this type of geospatial data could make it easier to visualise complex infrastructure projects and make certain government functions, such as tax collection, easier in mixed-use spaces. Other stakeholders felt that 3D data would aid in the management of flood risk and emergency preparedness.

There was an acknowledgement that investing in this type of data collection on a consistent nationwide basis would be expensive, and we were told that there may not be a single use case which justifies this investment. Other stakeholders told us that several organisations are currently carrying out high-quality work with 3D geospatial data. However, there are numerous standards in use, which limits interoperability and adoption.

Several stakeholders also highlighted the ongoing increase in the volume of geospatial data that is collected. We were told that the rapid increase in connected devices is producing a “tsunami of machine generated spatial data”. For example, in the context of smart cities, a huge variety of location-aware sensors incorporated within traffic lights, bus stops and streetlights are constantly collecting geocoded information. In some cases, the associated volume of information is placing strain on existing data collection and processing systems which were not designed with this scale of information in mind. Organisations are developing database technology that can harness this information and allow users to derive insights from this new data. These new systems allow users to develop more holistic answers to complex questions as they enable the integration of data from a large number of sources simultaneously, which would not have been previously possible.

Some of the public sector bodies we engaged with noted that they are increasingly relying on machine-learning techniques and AI to draw insights from the huge volume of data that they are collecting. Machine learning and AI were both highlighted as important future geospatial technologies in a recent review commissioned by the Geospatial Commission (Public, 2019)[127].

[127] https://www.gov.uk/government/publications/future-technologies-review

6 GEOSPATIAL USE CASES

6.1 Introduction

In this section we explore the use of geospatial data in three market segments:

- **Mobile phone network data** to capture aggregated patterns of individuals' movement.
  - We found that there are multiple steps involved in collecting, processing and analysing this type of data. The resulting products and services are demanded by end users from a variety of sectors, such as transport, marketing, retail and utilities as well as public sector organisations. These demand-side stakeholders value the nuanced insights the data offers because of its ability to identify fine-grained changes in activity, and aggregated movements of people over time and space.
  - There are a relatively small number of organisations which can supply this type of data due to the need to build up a mobile services customer base. This may make price setting more difficult in some cases and can reduce the willingness of certain demand-side organisations to engage. However, there are alternative data sources in the market which do not require this mobile services customer base, such as handheld device GPS data derived from applications.
  - Misconceptions about this type of data and the associated ethical considerations may be limiting further uptake in certain sectors although this does not seem to be the case across the board. The Geospatial Commission should work with public sector organisations to help them confidentially purchase these services where appropriate.
- Use of geospatial data **to develop automated mobility technologies**.
  - We found that geospatial data can play a vital role in the development of Autonomous Vehicles (AVs) via the provision of High Definition (HD) maps. These maps allow the vehicle to contextualise itself within a wider frame of reference and include static information on the basic road environment as well as more dynamic features like road markings or even traffic patterns. These maps are produced by different commercial organisations which have their own data collection mechanisms, some of which require significant upfront investment.
  - Data sharing will play an important role in this context. This will include sharing between organisations that are involved in the development of a single AV system as well as private sector companies sharing novel forms of geospatial data with public sector users. This type of data can provide information on the condition of road assets and highlight potential areas where accidents are more likely to occur. The Geospatial Commission could consider working with other organisations to learn from the success of existing data-sharing platforms.
  - Some stakeholders noted that there needs to be a certain degree of interoperability between different AV systems and their underlying geospatial inputs. We were told that this could help to ensure that different

vehicles can co-exist on the same road. However, other stakeholders felt that this was not a priority and the emphasis should instead be on ensuring that each individual system is sufficiently safe for driving on public roads. The Geospatial Commission could consider working with partner organisations to help ensure that enough interoperable information is shared to guarantee safety of AV systems and explore the value of additional interoperability.

- Adoption of geospatial data in the **insurance sector**.
  - We found that geospatial data is already being used in the insurance sector in a variety of ways. This includes more efficient processing of certain claims which can be identified or verified using geospatial data and better understanding of underlying risks, for example relating to geological features or flooding probabilities.
  - In many cases, public sector geospatial data is one of the key inputs which is used by stakeholders in this context. We were told that wherever possible public data should be geographically comprehensive, understandable in terms of what it is measuring and its limitations, and reliable in terms of its future availability. It may be helpful for the Geospatial Commission to explore tracking which public sector datasets are current being demanded by different user groups to help avoid a situation where a dataset that is heavily relied upon is altered or discontinued unexpectedly.
  - Stakeholders in this sector emphasised the importance of flexible licensing arrangements which are reflective of new use cases and emerging business models. The Geospatial Commission should consider facilitating these models where possible and learning from existing flexible access models built into the Public Sector Geospatial Agreement (PSGA), for example.

We describe detailed findings from each case study in a dedicated subsection below. In addition, relevant findings from each case study are reflected in the preceding sections of the report, which covered the entire geospatial ecosystem.

6.2 Mobile network data

6.2.1 Justification for inclusion in our study

Mobile network data is an emerging source of geospatial data. There is a wide variety of potential use cases for this type of information which the Geospatial Commission wanted to better understand. Insight from aggregate movement patterns can facilitate more efficient commercial activities or create new insights in response to complex questions from private and public sector data users. This data is currently gathered mostly by the private sector, sometimes as a by-product of other commercial activity. Therefore, it is also of interest to examine the public sector's role as a consumer in this context.

We explored the following questions:

- What value-adding activities are involved in the creation of data products and services from mobile network data and other forms of related data collection?
- How do competition, user choice and price setting operate in this context?

- What innovative products and services and new insights can be generated while protecting individual privacy?

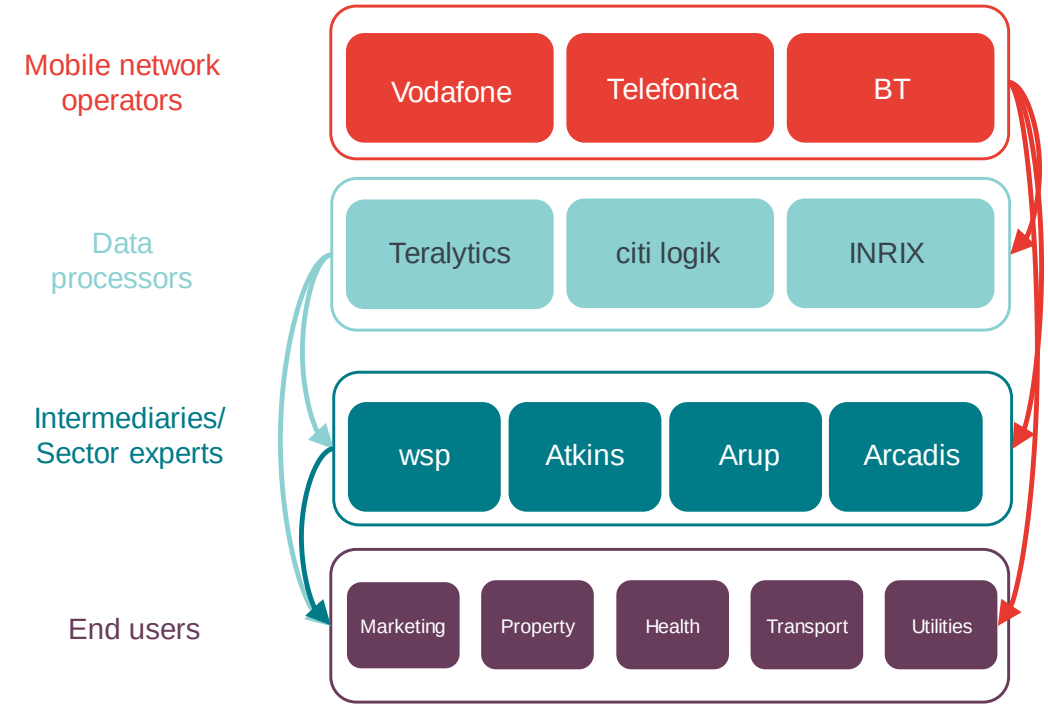
6.2.2 Mobile network data value chain

We developed an illustrative value chain showing the main activities involved in creating products and services based on mobile network data, presented in Figure 40 below. It is not intended to be exhaustive in terms of listing every organisation involved in this specific market segment, but we have provided examples of organisations that are active at each stage.

Mobile network operators collect data from individual devices when the devices interact with their respective networks (an interaction may be a call or a movement between non-overlapping cell towers). Each interaction generates a datapoint indicating the area in which that device is currently located. We were told that significant investment is then required to gather that data together and route it around the network. This is partially because huge volumes of data are involved, and network operators would not otherwise undertake this type of aggregation.

A number of steps are involved in packaging up data. This data firstly needs to be anonymised and then aggregated. Network operators and data processors emphasised that a lot of processing is involved in aggregating data across a large number of devices, correcting anomalies and carrying out preliminary calculations. These calculations could involve estimating journey times, for example. This process is very intensive computationally and involves millions of data points. Some stakeholders suggested that they have become more efficient over time at carrying out these activities.

Figure 40 Mobile network data value chain



Source: Frontier

In some cases, mobile network operators do this data processing themselves. Other operators have an ongoing relationship with an external organisation which does some of this work on their behalf. We were told that the decision to work with a partner or not largely depends on how much investment the network operator wants to make in its own data-processing capability.

The intermediate geospatial products produced at this stage of the value chain (by either the network operator or the dedicated data processor) are datafiles. These datafiles may then be incorporated into an existing transport model, for example. Stakeholders reported that a variety of additional data sources may also be included at this stage. These other sources could help to verify the accuracy of the mobile network data or to provide a more nuanced picture for the end user. These sources may include GPS data or Bluetooth data, which also provide information on movement patterns (see box below) or more traditional sources such as average traffic speed data from traffic cameras.

RELATED FORMS OF DATA COLLECTION

We were told that there is no perfect dataset which precisely tracks aggregate population movements. All stakeholders agreed that, while mobile network data can offer unique and valuable insights, it does have weaknesses. For example, in some cases, it is not precise enough for a particular application. This could include retail applications that require granular movement data within a specific store. Also, short journeys may not be picked up because the data is generated when a device transitions between cell towers that do not overlap.

We were told that data aggregation plays an important role in providing a more holistic picture. Some stakeholders told us that they use vehicle GPS data to complement mobile network data. This is because GPS data may, in some cases, provide a more accurate indication of average vehicle speeds, but mobile network data is much better at estimating how many cars are on the same stretch of road.

Market participants noted that handheld device GPS data derived from applications is also useful in some cases. However, this may have some inherent quality issues and biases. For example, some organisations may aggregate GPS data from numerous different apps which can reduce transparency. There may also be considerable churn of users who download an app and then delete it soon after. This makes trends hard to interpret reliably. Mobile data has a more stable user base.

Stakeholders told us how they combine mobile network data with project-specific information provided by their clients or partners to get a more complete picture. For example, the demand-side organisations may have data from their operational activities, such as ticketing systems or WiFi networks.

Multiple organisations were less enthusiastic about Bluetooth data in this context. We were told that it can be difficult to reach required sample sizes as users have to manually turn it on. In addition, for some applications, roadside sensors would have to be installed, which limits its attractiveness.

In some cases, the network operator or its partner processor works in conjunction with another set of intermediaries to produce the final geospatial products for clients. These intermediaries may include transport consultancies or sector experts such as marketing firms. We were told that they can help to contextualise the

mobile network information by combining it with other sources of information and may also use their specific expertise to provide a strategic overview of what the data implies. In addition, stakeholders in this category noted that they can help with the adoption of mobile network data into new sectors as they can leverage existing relationships with end users. This helps to increase trust in a new information source. In other cases, the network operator or the data processor works directly with the end client where the demand-side organisation has in-house analytical expertise (or the application is less computationally complicated). The nature of these final products or solutions varies depending on the client and the use case. It may include visualised interactive dashboards or reports which describe the data and resulting evidence. We describe specific examples in the next subsection.

Mobile network data use cases

We were told by multiple supply-side participants that transport is their most mature market and source of demand. Specific projects included forecasting demand in particular local authorities and examining the catchment areas of public transport hubs.

Other stakeholders described how they use mobile network data to appraise the deployment of new transport infrastructure projects and evaluate them post construction by examining redistribution of journeys.

Some users felt that mobile network data had been adopted by the transport sector relatively quickly because there are obvious existing sources of data collection such as roadside surveys or traffic cameras which mobile network data replaces.

Other stakeholders described how mobile network data is used to measure the effectiveness of out-of-home advertising and marketing campaigns. We were told that the data can help:

- Pre-campaign: planning a campaign to ensure the messages are placed in locations that will target the correct groups of consumers; and
- Post campaign: mobile data could, in the future, be used to observe behavioural change which could be attributed to the advertising. However, stakeholders reported that this specific use case was still in its infancy.

Suppliers of this type of geospatial information also work with retailers to explore customer behaviour and clients in the utilities sector to better understand patterns of demand.

Evolution in demand

Stakeholders told us that demand for mobile network data is evolving. Multiple interviewees noted that they are currently providing highly bespoke products which are developed for specific situations. We were told that they would like to explore developing more standardised products which could have a lower cost as some of the data processing would not need to be repeated each time. This could help enlarge the potential market and open up new use cases which previously were not feasible due to the associated costs.

More generally, multiple organisations outlined how COVID-19 is leading to increased demand for their services. For example, we were told that the current

crisis is changing people's behaviour so profoundly that it does not make sense to use old information, for example, on commuting patterns. This is leading to greater demand for live information and mobile network data can fill some of that gap. In addition, stakeholders described specific projects that are being carried out with mobile network data to help with the response to COVID-19, such as measuring demand for public transport.

Benefits of using mobile network data

Organisations that supply or make use of mobile network data described a number of its specific advantages (Figure 41). Firstly, we were told that using mobile network data relative to traditional data sources can provide more nuanced insights and holistic answers. This can occur in a number of ways. One demand-side organisation described how it can now view journey patterns on a day-by-day and even hour-by-hour basis, whereas previously it would have to rely on a single snapshot. This means it has a far more complete understanding of activity in its local area. Other organisations explained that the detailed nature of mobile network data means that they can provide insights that would only have been possible previously if multiple disparate data sources were combined (such as census data and surveys of road users).

Figure 41 User benefits from mobile network data

Source: Frontier

In addition, using mobile phone data can, in some cases, be cheaper than traditional data sources, depending on how data was gathered previously. For example, we were told that stopping cars at the roadside can be very time consuming and expensive. Mobile network data avoids the need for this type of primary data collection and does not require the installation of any physical infrastructure such as traffic cameras. Some demand-side users did note that purchasing this type of information can be costly.

Finally, several organisations noted that the information which can be derived from mobile network data is reliable. This is because it is evidence based and draws on large sample sizes. This avoids potential biases related to differential survey response and self-reporting error.

6.2.3 Provision of mobile network data is concentrated amongst a relatively small number of providers

As we described in Section 5, there was universal agreement that the market for collecting mobile network data (upstream supply) is concentrated amongst a small

number of providers who actively compete against each other. This is primarily because it is not possible to enter this market without a significant mobile customer base and, even within this group, not all mobile network operators originally devoted significant resources to this type of "non-core" activity. Entry barriers in the two intermediate stages of the supply chain are likely to be smaller and may relate to technical expertise and experience.

The end users we engaged with on the demand side of this segment signalled that they are able to choose between this limited pool of suppliers (and their partner organisations). We were also told that ordinary private sector use cases do not require incorporating multiple datasets from different providers. Stakeholders reported that they choose between providers on the basis of differences in price or industry experience. Some intermediaries have carried out their own market benchmark analysis to evaluate potential partners. In addition, individual demand-side organisations and intermediaries did note that they work with multiple providers across different projects.

However, supply-side participants told us that one consequence of a relatively immature thin market is that end users can be suspicious about the price that is being charged. Specifically, they are unsure if certain offerings represent good value for money. New users do not have an external benchmark to use as a comparison point and are unsure about the full value of engaging ahead of time.

Supply-side organisations noted that they can sometimes have difficulties in setting appropriate prices. This is because sometimes there is no obvious "going rate" and it can be challenging to quantify benefits ahead of time. We were told that this may be limiting demand in some cases. Some stakeholders suggested that the advent of the GDPR led to some app-based data providers ceasing to offer services to demand-side end users, which may have exacerbated this market thinness. In addition, some supply-side stakeholders told us that because selling this data is not their organisation's core activity, they have less experience of setting an appropriate price.

Some potential users of this type of data that we spoke to noted that they have not yet purchased this type of data. This is because, in their view, the quality is not yet high enough to justify the cost. However, this impression was not based on actual experience of engaging with the data in depth. Some suppliers noted that demand-side organisations are not always aware of the cost associated with processing the data. ***The Geospatial Commission should work with public sector organisations to help them confidentially purchase these services.***

6.2.4 There are opportunities to increase the usage of this type of geospatial data by raising awareness and overcoming misconceptions

Some users felt that the Geospatial Commission could have a role in sharing examples of where this data has been successfully implemented by public bodies in the past, to raise awareness amongst other public sector bodies. These case studies may help to overcome some concerns which still exist about the legitimacy of this type of data. They could also show the value of this type of data in a manner that is consistent with protecting individual privacy. ***In the recent UK Geospatial***

Strategy, the Geospatial Commission has committed to promoting the success of organisations that use location data, which could be beneficial in this context.

As we described in Section 5, some stakeholders in this sector felt that there are still some misconceptions amongst potential users. We were told that in certain segments customers may refuse to buy a product even if assurances have been given that all aspects of the data are fully compliant with regulations. This may be because the data is currently less commonly used in these sectors. We were also told by some supply-side organisations that they are cautious about publicly promoting their own capability in this area. This is because they are worried about public perception. This lack of promotion might reduce demand across the ecosystem more widely, and contribute to a lack of demand-side awareness.

Some public sector demand-side organisations noted that they would have valued central guidance on usage the first time they engaged with the data. This suggests that there may be opportunities for knowledge sharing across the public sector.

Other private sector intermediaries felt that this was not a significant barrier and, by and large, this type of data is accepted. This difference of opinion may reflect the fact the different sectors are at different points in terms of their levels of adoption.

6.3 The role of geospatial data in the development of autonomous vehicles

6.3.1 Justification for inclusion in our study

Autonomous vehicles (AVs) have the potential to transform large sections of the economy as well as individuals' day-to-day lives. Geospatial data has an important role in facilitating this transition. Policy continues to evolve in this area and there would clearly be significant international interest in the development of a successful AV ecosystem, as other countries are grappling with the same issues.

We explored the following questions:

- What role do geospatial data and HD machine-readable maps play in the development of AV systems?
- What role will data sharing play in this context in the future?
- How important is interoperability of data in this segment?

6.3.2 Autonomous vehicle geospatial value chain

Role of HD maps and geospatial data

Sensors are the primary sources of information for an AV. AVs use a feed of data from sensors to perceive the road environment, track moving objects and pick up on visual cues like road markings. These sensors may be based on a range of different technologies such as LiDAR (emission of laser signals), RADAR (emission of radio waves) or high-quality cameras.

In addition, AVs generally require a HD machine-readable map to augment the sensor data.[128] These maps can provide a fail-safe system, if for example sensors fail and allow the AV to contextualise the sensor data within a wider frame of reference. The maps can also provide a means of path awareness and foresight. Specifically, we were told that there are relevant objects such as road signs that the cameras or sensors may not be able to see at all times. This could happen, for example, if the sensors' view is temporarily obstructed by another road user. The HD maps may provide this information in those cases.

To generate these maps, we were told that three types of geospatial data are needed:

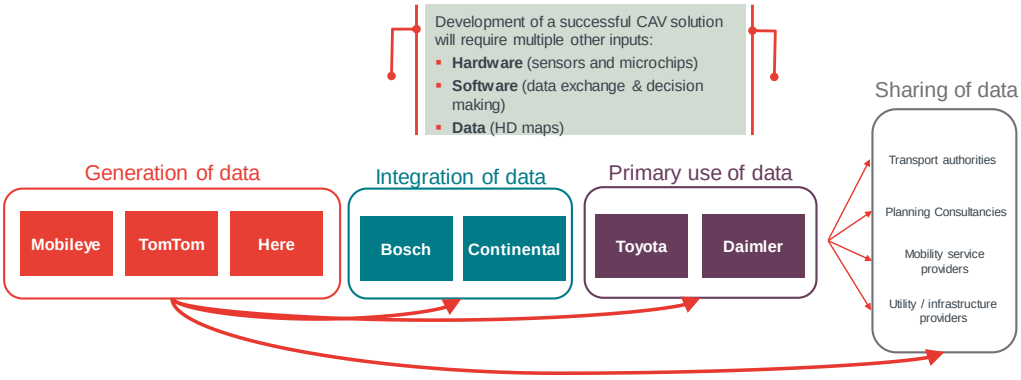
- base mapping, which is a high-resolution machine-readable version of a set of static assets;
- contextual information on what surrounds vehicles to enable decision making, which needs to be continually updated to reflect changes in road markings/street furniture; and
- real-time ultra-dynamic information on temporal hazards like floods or traffic, which allows vehicles to make better decisions about routing, for example.

Segmentation of participants

The AV ecosystem is very complex and involves multiple different technology layers. This includes hardware aspects, such as sensors, and software elements so that the car can exchange data with the cloud and make decisions.

In Figure 42 below, we set out the different activities involved in the geospatial value chain that feeds into AVs. We also set out potential external use cases for geospatial data collected by AVs.

Figure 42 AV Geospatial data value chain



Source: Frontier

We do not attempt to articulate each step involved in the development and production of AVs. Instead, we focus on the role of geospatial data in the sector and provide examples of organisations that are active at different stages.

We were told that the creation of many automated driving systems is overseen by Original Equipment Manufacturers (OEMs). These are major car manufacturers like Toyota or Daimler which have traditionally focused on the design and assembly

[128] Not all AVs follow this model. Some rely purely on sensor technologies.

of vehicles. These organisations can coordinate the development of AV solutions and put out specific tenders to the market for services related to AVs.

These OEMs are served by a range of Tier 1 companies which supply parts or systems directly to OEMs. In this case, Tier 1 companies include organisations like Bosch and Continental which develop a range of sensors, vehicle computers, operating systems and software for the AV market.

Some dedicated HD mapping providers have a relationship with both OEMs and Tier 1 companies. Mapping companies supply the geospatial components for AVs, which are then integrated into the overall AV system (which also features sensor technology and decision-making software, for example). These geospatial mapping providers need to have technical relationships with Tier 1 firms to ensure compatibility with the overall automated driving stack.

In other cases, a single organisation provides both the sensor technology and the geospatial mapping element to a Tier 1 company or directly to an OEM. This could also include the decision-making software and user interface.[129]

Connected AVs collect data on their environment during each journey. During these trips, the vehicles are constantly ingesting data on the road environment and other road users. As we describe below, this is necessary to update or create the underlying HD maps which enable AV development. However, stakeholders highlighted several wider uses for this type of data. Public sector organisations, transport authorities or infrastructure providers could use this type of data in a number of ways. For example, it could be used to assess the changing condition of assets such as road surfaces, or inform the redesign of junctions where harsh braking is frequently required. This data could come from OEMs or from technology providers at earlier stages of the value chain. We discuss this type of data sharing in more detail below.

6.3.3 Competition in the provision of HD mapping services

We were told that HD mapping provision in Europe and the USA is concentrated amongst a small number of firms which compete actively against each other. These firms are either organisations that previously developed in-car navigation systems or specialist AV technology providers.

We were told by some market participants that the initial development of HD maps can require a huge upfront investment which constitutes a major entry barrier. Specifically, some stakeholders noted that creating a HD map from scratch can require dedicated data collection on a vast scale. Some organisations create their HD maps by undertaking a dedicated data collection process. This may involve driving a large number of data collection vehicles that are fitted with specialised equipment on all roads of interest. These maps can then be updated on an ongoing basis by connected vehicles which collect data while making ordinary day-to-day trips that can be incorporated into this existing framework.

Other organisations rely entirely on crowdsourced data from vehicles fitted with sensors and there is no dedicated upfront data collection phase. The vehicles that

[129] Not all AV solutions follow this model. In some cases, a single organisation develops the majority of hardware, software and chips that power the AVs internally and then equip existing models of cars with their own self-driving technology

collect this information are not fully autonomous initially but include some form of sensor technology that can provide basic driver assistance and gather relevant data. We were told by stakeholders that this may be a more cost-effective option. However, this does not itself encourage entry as the system is reliant on a high volume of users in order to maintain up-to-date maps. These providers can acquire users by retrofitting sensors onto fleets of commercial vehicles or including their driver assistance systems on newly built cars.

Firms active in the provision of HD maps told us that OEMs choose their provider based on existing relationships or perceptions of quality and fit within the wider AV system.

6.3.4 Role of policy in driving the development of the AV ecosystem

Interoperability of different HD maps

Multiple stakeholders told us that the different HD maps always describe the real world in slightly different ways. This is because they are created by different organisations as part of differently evolving AV systems.

Stakeholders did note that in some cases rival systems could result in some duplication and additional investment of resources. However, this was viewed as largely unavoidable. We were told that a one-size-fits-all approach does not make sense in this context. Stakeholders emphasised that if there was one single source of HD mapping data, the responsible provider may have limited incentives to make improvements. This in turn could lead to an increase in safety issues in the long term if competitive pressures were not maintained. This suggests that there are benefits to the development of multiple HD maps, each having a substantial user base.

AVs' appreciation of the world around them can come from both sensors and maps (sensors can give an indication of distance but do not always have the full context that is important for decision making). Some stakeholders did report that different AVs may need a common sense of where they are in relation to each other. This could require a common way of thinking about the real world even if people describe the details differently. Some stakeholders told us that facilitating this type of interoperability could reduce the safety risks associated with two different mapping systems interacting in the real world which have different underlying representations of the real-world environment.

Other participants active in this segment felt that this level of interoperability was unnecessary. One organisation told us that its own system can operate alongside human drivers, who are also slightly different and interpret information in unique ways. The AV decision-making architecture that they are developing does not involve any communication with other vehicles. As a result, they do not see the value associated with the interoperability we describe above.

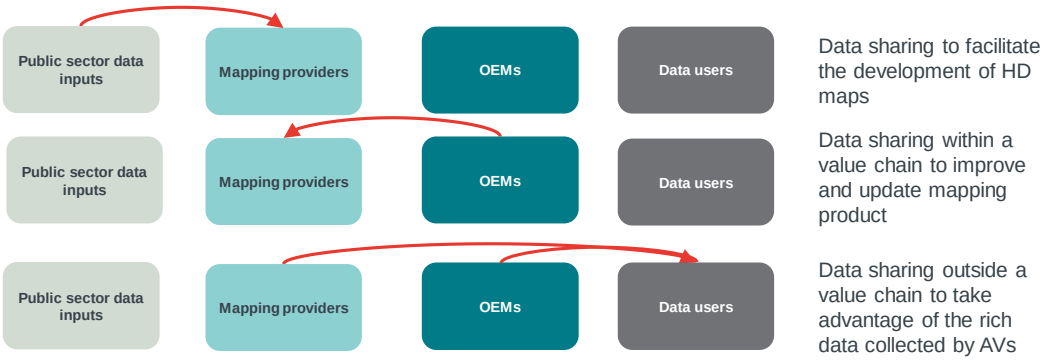
Stakeholders did, however, acknowledge that different AV systems may not be as safe as others. As a result, some participants told us that the most important role for a regulator in this space was to accurately determine which AV systems are safe enough to operate in public. This is in keeping with previous work carried out

by Zenzic (2020). Zenzic was created by government and industry to focus on key areas of UK capability in the self-driving sector. It recommended that while manufacturers may be reluctant to share data and methods, safe self-driving vehicle operation will nevertheless be dependent on conformity to a minimum set of safety requirements and associated standards.[130] ***The Commission should consider working with partner organisations to help ensure that enough interoperable information is shared to guarantee the safety of AV systems and explore the value of additional interoperability.***

Data sharing

We discussed several different types of data sharing with stakeholders in this area. We visualise three specific examples below in Figure 43 and then discuss each in turn.

Figure 43 Data sharing in the AV ecosystem



Source: Frontier

Gathering public sector input data to inform the development of HD maps

Some mapping providers felt that provision of specific types of high-quality public sector data was important for the efficient development of high-quality HD maps. In particular, we were told by a mapping provider that having that accurate addressing data is increasingly important (both currently in existing navigation products and also for HD maps in the future). Some frustrations were expressed around access models for this type of data. Specifically, it was seen as very expensive relative to other countries. We were told that this may be because the UK data is very high quality and international comparisons may be misleading because the UK system is unique.

Some mapping stakeholders did put forward the view that there would be benefits from having a single authoritative source of data on the road network (such as lane pathways) and road furniture. This was viewed as inaccessible currently. This is in keeping with previous research carried out by Zenzic (2020)[131] which concluded that: "*the quality of public data can often be poor and have discrepancies within a dataset. There are over 200 Local Highway Authorities in Great Britain alone – which can present a problem with the number of different processes and data handling methods used*". We were told by these stakeholders that government

[130] https://zenzic.io/content/uploads/2020/06/Geodata-Report-June-2020.pdf
[131] https://zenzic.io/content/uploads/2020/06/Geodata-Report-June-2020.pdf

should consider freely publishing source information on changes to road furniture, for example, which would allow mapping companies to update their maps without having to drive the roads and collect the data manually.

Public sector stakeholders agreed that this type of information is not currently available in a single location. In some cases, it may be collected by multiple different local organisations and it may not have been compiled. ***The Commission should consider whether centralising and standardising some of the fragmented data would be worthwhile and/or whether improving signposting would increase the visibility of existing data locations.*** However, any government policy will come with associated costs. These costs may apply both directly to the government and possibly more widely if, for example, there are firms that are currently attempting to provide this information to others. This trade-off would have to be carefully considered.

It is also possible that technological advances may mean that this type of input data provision becomes less important in the future. Some market participants who develop their own HD maps told us that, by and large, they would not benefit from this type of publicly provided data. This is because their maps do not include external data sources and are entirely based on data collected from sensors. Therefore, any policy recommendation would have to weigh up the possible future direction of technological advances to avoid subsidising out-of-date technology. Even in these cases, there may be benefit in sharing real-time information such as traffic light transmissions. We were told that, currently, there are constantly updating sources of information or updating maps that tell you if a traffic light has changed.

Data sharing within a value chain to facilitate creation and improvement of HD maps

As we described above, all stakeholders agreed that it is necessary to build in a crowd-sourced element to create HD maps or facilitate their development and evolution. This involves each AV providing information back to the mapping company via data sharing. We were told that the level of precision and accuracy required means that the maps need to be very up to date. It is not affordable to collect this data on an ongoing basis using manual data collection from survey vehicles.

Some mapping companies described how, in some cases, they need to negotiate with OEMs to facilitate this data-sharing process. Specifically, we were told that it is important to establish the mutual value associated with that transfer of information. From the point of view of the mapping companies, that data allows them to either create a HD map or carry out updates in a cost-effective way. From the OEMs' perspective, this data sharing leads to the improvement of the HD maps, which ultimately creates a superior AV product that will benefit their customers.

Data sharing beyond an individual value chain for a variety of non-AV use cases

Mapping firms told us that they can offer useful information to a range of users in different segments. This could include information from established navigation

products which have collected years of traffic data, for example. This data could be used by highways authorities to explore demand. In addition, several market participants noted that the data that AVs collect to facilitate the map development described above also has a range of other potential uses. For example, one company active in this sector described how it has recently started to market its data which has several use cases, including road asset surveys for infrastructure providers. Data collected by vehicle sensors can replace inventory surveys and could allow users to rapidly detect changes such as cracks in the road surface. We were also told that AVs can collect data near-misses in terms of potential accidents. City planners can see junctions that typically require drivers to engage in harsh braking or areas where AVs are in close proximity to cyclists.

Other users agreed that there are a wide range of possibly mutually beneficial data-sharing partnerships that could be put in place. However, we were told that, currently, there may be a lack of compelling reasons to share data more widely in some cases. This may be because the value of engaging in a data exchange is not clear to both parties. Stakeholders described emerging platforms for sharing and exchanging mobility data that may help with this issue in the future. Specifically, these platforms help to uncover business cases for using this type of data and mechanisms which incentivise an equitable exchange of data. ***The Commission should consider working with partner organisations to learn from the success of existing data-sharing platforms.***

6.4 Use of geospatial data in the insurance sector

6.4.1 Justification for inclusion in our study

The insurance sector has been identified as a potential major user of geospatial data. Geospatial data is currently being applied in a variety of innovative ways by start-ups and established players in the sector. However, adoption is not yet commonplace. The Commission is therefore interested in understanding any barriers to adoption. Public bodies also collect a variety of geospatial data that can be of use to stakeholders in the insurance sector. Therefore, we explored how current licensing and access policies are viewed by stakeholders in this area and whether potential improvements could be made. Finally, technological advances may change certain geospatial segments that are particularly relevant to this space. We considered the possibility of bypassing traditional sources of information using new data collection methods which can provide information on what the public sector's future role may be.

We explored the following questions:

- How is geospatial data currently being used in the insurance sector?
- What type of publicly provided geospatial data products and services are in demand?
- How do stakeholders in this context want to license and access public sector geospatial data?
- How important is interoperability of data in this segment?

6.4.2 Application of geospatial data in the insurance sector

Stakeholders noted that a range of geospatial data is currently used in the insurance sector for a variety of purposes (Figure 44).

Figure 44 Use cases for geospatial data in the insurance sector

Source: Frontier

Geospatial data can allow insurance companies to better assess and measure risks. For example, some organisations incorporate geospatial data on flood risk patterns to generate a more nuanced understanding of the likelihood of future flooding. This improved understanding means that insurance providers are more willing to offer coverage (at an appropriate price level) as they have a greater degree of confidence in the probability of incurring a loss. As a result, a wider range of end consumers can access insurance products.

Geospatial data can also be used to make some existing administrative business processes in the insurance sector more efficient. Stakeholders told us that geospatial data is currently being used to help streamline the claims process. Geospatial earth observation can be used to verify that a loss has occurred (as a result of a natural disaster, for example). This eliminates the need for manual verification to take place. As a result, the insurer's costs are lower and the customer is able to secure their pay-out more quickly.

Finally, stakeholders described how geospatial data can be used to reduce the likelihood of an insurance claim materialising by changing the behaviour either of insurance providers or those who are seeking coverage. We were told that dynamic geospatial data can provide live information on the risk associated with a specific activity. For example, undertaking a journey or operating a vehicle as a result of dynamic localised factors like weather conditions and nearby activity. Provision of this type of information and associated flexible pricing models can incentivise consumers to only engage in certain behaviours during less risky periods. Alternatively, other stakeholders described how the use of earth observation data by insurance providers can act as an early warning signal that a particular piece of infrastructure is at risk of collapse. In that way, geospatial data can be used as a basis for preventative interventions which reduce the chances of a loss occurring which would otherwise have led to a claim.

6.4.3 Use of public sector geospatial data in the insurance sector

We also wanted to examine the current importsance of public sector geospatial data as an input in this context. We were told that one of the major challenges for start-ups that are trying to develop a new business model in the insurance sector

is finding the appropriate data. In many cases, geospatial modelling is carried out to facilitate a more nuanced understanding of risk. We were told that there are a range of different factors that can impact risks in different contexts, and adequate data across all these drivers may not exist.

We were told that a range of geospatial data products and services collected and provided by public sector organisations are used in this context. In particular, stakeholders described how foundational geospatial assets like addressing products are used in the insurance sector. Also, multiple stakeholders told us that geological data collected by public bodies on, for example, historical mining activity and geological risk factors can be a useful source of input information for the sector. Also, public weather data and flood maps are used in this context.

Stakeholders described a number of characteristics which will encourage commercial organisations to make even greater use of these foundational geospatial assets (see Figure 45 below).

Figure 45 Characteristics of useful public sector data

Source: Frontier

Stakeholders emphasised the importance of public sector data being geographically comprehensive. This is most relevant for use cases which require a national picture. It is also expected as a minimum standard when datasets are published by public bodies. In some cases, stakeholders described how they have to invest time trying to make different geospatial datasets across the UK's four nations consistent.

We were told that public data also needs to be understandable. It should be clear what the data is measuring and its limitations. This serves to emphasise the importance of ensuring that any data is accompanied by comprehensive metadata, in line with the recommendations of the Digital Land Review. This metadata should set out what information is included and how variables are defined, as well as ongoing curation and update schedules.

Finally, stakeholders told us that data needs to be reliable in terms of its availability. Commercial organisations need to know that currently available data will continue to be made available in a suitable format. We were told that start-ups need to have confidence in future availability in order to make commitments to customers. ***To help facilitate this, the Commission should explore tracking which public sector datasets are currently being demanded by different user groups, to help avoid a situation where a dataset that is heavily relied upon is altered or discontinued unexpectedly***.

Licensing of public sector data

Start-ups increasingly want to pay for data on a per-use basis and access data via API calls. This is due to their flexible and rapidly evolving business models. As a result, any data that they use should ideally be licensed on a flexible basis.

Start-ups in the insurance sector noted that they are seeking specific aspects of public sector data. In some cases, these precise attributes may not have been required in isolation previously (this may include the location of specific points of interest around the country, for example). The use of granular API calls means that start-ups do not have to pay to host large datasets and they can focus on the specific data elements that are relevant for their use case.

Some of the interviewees we spoke to in this context expressed frustration that they could not access the precise data elements they were looking for. They felt that the only option was to pay for a bulk download of entire datasets which included lots of features that they did not need. Other stakeholders did tell us that they have had positive experiences using public sector APIs to access geospatial data. Flexible pricing models enabled them to develop business models that would not have been possible if they were required to pay upfront. This difference primarily reflects different data demands, which may or may not be catered for currently by public sector bodies. ***The recently agreed Public Sector Geospatial Agreement (PSGA)[132] is an example of how public sector data can be accessed on a granular basis. The quality of public sector data is generally high. However, some users did note that local authority data provision can be inconsistent. The Commission plans to work with partners to invest in the quality of public sector location data.***

6.4.4 Awareness of the value of geospatial data and current adoption within the insurance sector

Overall, stakeholders told us that awareness of geospatial data and the value it can bring to the insurance sector is mixed.

Multiple stakeholders told us that while established insurance companies understand the benefit of engaging with geospatial data, there are still some parts of the insurance industry that are reluctant to embrace change. This may be because there is some degree of cultural reluctance to adopt new processes and sources of information. Some stakeholders felt that certain parts of the industry are very slow moving and large established companies are reluctant to deviate from established ways of doing things. It may be that competitive pressures mean that industrywide adoption occurs over time as geospatial data offers early adopters an efficiency advantage.

It may also be the case that certain parts of the insurance sector are quicker to adopt geospatial data where the additional value is greater. Specifically, this differential adoption may be because innovative geospatially informed insurance offerings are more likely to be taken up in emerging insurance sub-sectors. These areas may include new forms of transport like shared mobility where established

[132] https://www.ordnancesurvey.co.uk/business-government/public-sector-geospatial-agreement

insurance models may not yet fully exist. As a result, it is easier to develop a new offering which is partially underpinned by geospatial insights. We were also told the geospatial data may have been more readily embraced in market segments where traditional models exist but have struggled in the past, such as flooding, where providers are more willing to engage with something new.

Geospatial organisations active in this sector described how a key part of their work is to educate consumers around the value of high-quality data in this context. They noted that, in some cases, trying to market new products to new customers is a considerable challenge.

They also told us that this further reinforces the importance of input data availability, as we described above. We were told that a new end user in the insurance sector will not engage with a new data product unless the geospatial provider can give assurances that it will be made available on an ongoing basis without major swings in price. The geospatial provider can only do this if it has confidence in the long-term availability of the underlying input data.

We were told that one of the best ways to overcome awareness barriers is via the facilitation of linkages between innovative start-ups and established industry stakeholders. Several stakeholders described the value of different initiatives which attempt to do this. These include accelerators and geospatial data hubs, which were viewed positively. ***The Commission should consider exploring opportunities to support these types of initiatives in conjunction with partners across the sector.***

6.4.5 Possible implications of technological innovations in this context

Several stakeholders told us that technological progress is continuing to impact the collection and processing of geospatial data. For example, some interviewees reported that satellites are getting smaller over time and so it is easier to commercialise space-related earth observation opportunities. This has opened up new data use cases in the insurance industry. For example, this may include examining how floods are happening in real time, or pinpointing minor land movements which could provide an indication of future subsidence. We were told that costs may continue to fall in the future, which could lead to the development of further applications.

In some cases, this may mean that in the future there will be less need for some of the geospatial data that is collected by public bodies on geological characteristics or property boundaries, for example. However, participants did note that for some applications below ground, public sector data is still very much needed. We were told that earth observation and satellite data can provide useful information on potential ground movements, but they cannot always tell what is going on beneath the ground to generate that movement. Interviewees therefore felt that geological data can be powerfully used in conjunction with these newer forms of geospatial data. Specifically, the publicly held underground data can be used to carry out probabilistic and predictive modelling, which are crucial for determining risk. The satellite data can help to validate and improve the model to see if the ground moved in accordance with predictions.

7 BIBLIOGRAPHY

Attard, J., Orlandi, F. and Auer, S., 2016, October. Data value networks: Enabling a new data ecosystem. In 2016 IEEE/WIC/ACM International Conference on Web Intelligence (WI) (pp. 453-456). IEEE.

BEIS, 2019. UK Innovation Survey 2019. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/903582/UK_Innovation_Survey_2019_Main_Report.pdf

Bennett Institute for Public Policy, 2020. Valuing Data. bennettinstitute.cam.ac.uk/research/research-projects/valuing-data/

Brennan, R., Attard, J. and Helfert, M., 2018. Management of Data Value Chains, a Value Monitoring Capability Maturity Model.

Burning Glass, 2019. No Longer Optional: Employer Demand for Digital Skills. https://www.burning-glass.com/wp-content/uploads/no_longer_optional_report.pdf

Cabinet Office, 2018. An Initial Analysis of the Potential Geospatial Economic Opportunity https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/733864/Initial_Analysis_of_the_Potential_Geospatial_Economic_Opportunity.pdf

CMA, 2020. Online Platforms and Digital Advertising: Market Study Final Report. https://assets.publishing.service.gov.uk/media/5efc57ed3a6f4023d242ed56/Final_report_1_July_2020_.pdf

Coppa, I., Woodgate, P. and Mohamed-Ghouse, Z., 2018. Global Outlook 2018: Spatial Information Industry. https://www.crcsi.com.au/assets/Resources/CRCSI-Global-Outlook-Report-2018.pdf

Deloitte, 2017. Assessing the Value of Tfl's Open Data and Digital Partnerships. http://content.tfl.gov.uk/deloitte-report-tfl-open-data.pdf

European Commission, 2017. Big Data in Earth Observation. https://ec.europa.eu/growth/tools-databases/dem/monitor/sites/default/files/DTM_Big%20Data%20in%20Earth%20Observation%20v1.pdf

Geobuiz, 2019. GeoBuiz 2019 Report: Geospatial Industry Outlook and Readiness Index. https://geobuiz.com/geobuiz-report-2019/

Geospatial Commission, 2018. National Geospatial Strategy – Call for Evidence. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/734331/Geospatial_Commission_call_for_evidence_2018.pdf

Geospatial Commission, 2019 A. Geospatial Commission Call for Evidence – Submitted Responses. https://www.gov.uk/government/publications/geospatial-commission-call-for-evidence-responses

Geospatial Commission, 2019 B. Geospatial Commission Annual Plan 2019–2020. https://www.gov.uk/government/publications/geospatial-commission-annual-plan-2019-2020

Geospatial Commission, 2020. Unlocking the Power of Location: the UK's Geospatial Strategy. https://www.gov.uk/government/publications/unlocking-the-power-of-locationthe-uks-geospatial-strategy

Goldfarb, A., and Tucker, C., 2019. Digital Economics. *Journal of Economic Literature* 57(1), p 3-43

House of Commons Business, Innovation and Skills Committee, 2016. The Digital Economy: Second Report of Session 2016-17. https://publications.parliament.uk/pa/cm201617/cmselect/cmbis/87/87.pdf

House of Commons Library, 2019. Briefing Paper: Business Statistics. https://commonslibrary.parliament.uk/research-briefings/sn06152/

HM Treasury, 2018 A. The Green Book: Appraisal and Evaluation in Central Government. https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent

HM Treasury, 2018 B. The Economic Value of Data: Discussion Paper. https://www.gov.uk/government/publications/the-economic-value-of-data-discussion-paper

Law Society, 2019. CON 29 Guidance Notes. https://www.lawsociety.org.uk/topics/property/con29-forms

London Economics, 2017. Economic Impact to the UK of a Disruption to GNSS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/619545/17.3254_Economic_impact_to_UK_of_a_disruption_to_GNSS_-_Showcase_Report.pdf

London Economics, 2019. Size & Health of the UK Space Industry 2018. A Report to the UK Space Agency. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/774450/LE-SHUKSI_2018-SUMMARY_REPORT-FINAL-Issue4-S2C250119.pdf

Longhorn, R.A. and Blakemore, M., 2008. Geographic Information: Value, Pricing, Production, and Consumption. CRC Press.

National Audit Office, 2019. Challenges in Using Data Across Government. https://www.nao.org.uk/wp-content/uploads/2019/06/Challenges-in-using-data-across-government.pdf

Nesta, 2014, A Map of the UK Games Industry. https://www.thecreativeindustries.co.uk/media/274111/map_uk_games_industry_wv.pdf

Nesta, 2018, Flying High Shaping the Future of Drones in UK Cities.

https://media.nesta.org.uk/documents/Flying-High-full-report-and-appendices.pdfODI, 2018. The UK's Geospatial Data Infrastructure: Challenges and Opportunities. https://theodi.org/article/geospatial-data-infrastructure-report/

Office of Fair Trading, 2009. Government in Markets. Why Competition Matters – a Guide for Policy Makers.

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/284451/OFT1113.pdf

Office for National Statistics, 2019. UK Business; Activity, Size and Location: 2019. https://www.ons.gov.uk/businessindustryandtrade/business/activitysizeandlocation/bulletins/ukbusinessactivitysizeandlocation/2019

Open Data Institute, 2018. The UK's Geospatial Data Infrastructure: Challenges and Opportunities. https://theodi.org/wp-content/uploads/2018/11/2018-11-ODI-Geospatial-data-infrastructure-paper.pdf

Phillips, R. L. (2001). The Management Information Value Chain. Perspectives, 3.

Public, 2019. Future Technologies Review. https://www.gov.uk/government/publications/future-technologies-review

Royal Society, 2019. Dynamics of Data Science Skills. https://royalsociety.org/-/media/policy/projects/dynamics-of-data-science/dynamics-of-data-science-skills-report.pdf?la=en-GB&hash=212DAE7D599B0A48687B372C90DC3FEA

Spataro, J. and Crow, B. (2002). A Framework for Understanding the Information Management Market.

Transport Systems Catapult, 2016. Utilising Mobile Network Data for Transport Modelling. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/662948/utilising-mobile-network-data.pdf

United Nations Committee of Experts on Global Geospatial Information Management, 2018. Integrated Geospatial Information Framework. https://ggim.un.org/meetings/GGIM-committee/8th-Session/documents/Part%201-IGIF-Overarching-Strategic-Framework-24July2018.pdf

United Nations Economic and Social Council, 2018. Determination of Global Fundamental Geospatial Data Themes. http://ggim.un.org/meetings/GGIM-committee/8th-Session/documents/E-C20-2018-7-Add_1-Global-fundamental-geospatial-data-themes.pdf

Zenzic, 2020. Geodata Report – Analysis and Recommendations for Self-driving Vehicle Testing https://zenzic.io/content/uploads/2020/06/Geodata-Report-June-2020.pdf

ANNEX A QUALITATIVE RESEARCH

This annex provides additional detail on our qualitative research approach.

A.1 Example topic guide

Figure 46 Supply-side company generic topic guide

Supply Side Firm Topic Guide		
Research priority		**Question**
Defining and understanding the geospatial data market	1	What activities does your firm carry out at each stage of the value chain? •collection and acquisition of data •data transformation •data interlinking and integration •internal exploitation of data •producing data products and services
	2	How have your activities in the value chain evolved?
	3	Which of these activities would you consider your primary task (and where do you spend the most time)? In which areas are you planning to expand your activities?
	4	Which of these areas of activity require the greatest upfront investment (e.g. staff time, purchase of technology, licencing)?
	5	What data products and services do you use as inputs into your service? What barriers do you encounter (e.g. licencing, cost etc.)
	6	Who are the users of your data and services and are you aware of subsequent activities they carry out with your data?
Functioning of the geospatial data market	7	Why do you engage your customers and what are the key changes you have seen in customer expectations?
	8	Who, if anybody (including public sector organisations), do you consider to be competitors for the products and services you sell? Have you seen a change in the level of competition?
	9	What, if any, barriers to entry / exit exist? How often do firms enter or leave the market?
	10	What determines your pricing strategy across various commercial products and services?
	11	How do individuals / does society benefit from your data products / services?
	12	Are existing and potential customers well informed regarding the availability and value of your geospatial data and services?
	13	Do you have access to the inputs you need (skills, finance, other members of the ecosystem)?
	14	How can third-party private sector or public sector data be complementary with the data and services you provide? Could it also be a substitute in some cases?
	15	Are you aware of the demand for your geospatial data assets?
	16	What incentives do you have to share your geospatial data currently?
	17	What would encourage you to share your data more widely?
	18	What issues do you encounter when accessing public sector geospatial data?
	19	Is there any data that you cannot access that would improve your commercial offering or societal value?
Commercial activity in the geospatial data market	20	How is demand for your data and services evolving from the perspective of companies that you supply and your customers' end users?
	21	Is there any public sector demand for your data and services?
	22	How do you identify your target market and increase awareness?
	23	How do you market your geospatial data products and services?
Opportunities in the geospatial data market	24	Are there any organisations that would benefit from greater use of your data and services?
	25	What previous / existing UK policy initiatives in this context should we learn from?
	26	What innovations will shape the geospatial data market in the near future and how is your organisation planning to adopt these into their activity?
	27	Are there barriers currently to the ongoing development of the UK geospatial market?

Source: Frontier

ANNEX B MARKET IDENTIFICATION METHODOLOGY

This annex provides additional detail on our methodology for identifying and sizing the core geospatial companies. Section 3 of this report presents a detailed summary of the quantitative findings from this exercise.

B.1 Search terms and sector lists

The terms and sector lists (for Tier 2) are provided for glass.ai below as an example. The sector classifications are slightly different across the different data sources. However, we applied similar tiering rules across all platforms. We discuss differences in inclusion and exclusion rules in the following subsection. We manually reviewed the sector lists and search terms with the Geospatial Commission as part of the quality assurance process to ensure a high level of consistency.

Tier 1 rule

- *Geospatial*: Iterations of geospatial such as geo-spatial, geo - spatial and geo spatial should be included too.

Tier 2 rule

- Companies were included if they were classified as operating in specific sectors judged to involve geospatial activity and had descriptions that included specific geospatial search terms. For example, if the company operates in the "***property***" sector and its company description contains search terms such as "***aerial survey***", "***autonomous vehicle***" and "***cadastral***", then it would be counted as a Tier 2 geospatial company.

Figure 47 glass.ai sectors included in Tier 2

Sector Grouping	Sector	Sector Grouping	Sector
Consumer Goods and Services	Consumer Products and Services	Professional Services	Accounting
Consumer Goods and Services	Retail	Professional Services	Business Supplies and Equipment
Consumer Goods and Services	Wholesale	Professional Services	Consulting
Energy and Environmental	Environmental Services and Conservation	Professional Services	Design
Energy and Environmental	Oil and Energy	Professional Services	Information Services
Energy and Environmental	Renewables and Sustainability	Professional Services	Law Practice and Services
Energy and Environmental	Utilities	Professional Services	Market Research
Financial Services	Banking	Professional Services	Marketing and Advertising
Financial Services	General Financial Services	Professional Services	Outsourcing and Offshoring
Financial Services	Insurance	Professional Services	Public Relations and Communications

Sector Grouping	Sector	Sector Grouping	Sector
Financial Services	Investment Banking and Advisory	Professional Services	Security and Investigations
Financial Services	Investment Management	Real Estate and Construction	Architecture and Planning
Government	Central and Local Government	Real Estate and Construction	Civil Engineering
Government	Government Agencies and Other Public Bodies	Real Estate and Construction	Construction
Healthcare and Scientific	R&D and Scientific	Real Estate and Construction	Facilities Services
Industrial and Agriculture	Agribusiness and Fishery	Real Estate and Construction	Real Estate and Property Management
Industrial and Agriculture	Aviation, Aerospace and Defense	Supply Chain and Transport	Automotive
Industrial and Agriculture	Electrical and Electronic Manufacturing	Supply Chain and Transport	Import and Export
Industrial and Agriculture	Industrial Automation	Supply Chain and Transport	Logistics and Supply Chain
Industrial and Agriculture	Machinery	Supply Chain and Transport	Maritime
Industrial and Agriculture	Mechanical and Industrial Engineering	Supply Chain and Transport	Transportation, Trucking and Railroad
Industrial and Agriculture	Mining and Metals	Supply Chain and Transport	Warehousing
Leisure and Hospitality	Leisure, Travel and Tourism	Technology	Computer Games
Media and Arts	Online Media	Technology	Computer Hardware
No sector firms		Technology	Computer Networking and Security
		Technology	Computer Software
		Technology	Information Technology and Services
		Technology	Internet
		Technology	Semiconductors and Electronic Systems
		Technology	Telecommunications and Wireless

Source: Frontier analysis

Figure 48 Tier 2 search terms

Search terms		
aerial survey	geo-fencing	meteorology
aerial surveying	geographic data	mineral exploration
asset mapping	geographic information	mobile mapping
atmospheric research	geographic information system	navigation charts
automatic vehicle location	geographical information	navigation devices
autonomous system	geographical information system	navigation equipment

Search terms		
autonomous vehicle	geointelligence / geo-intelligence / geo - intelligence	oceanography
autonomous vessel	geolocation / geo-location / geo - location	oil exploration
building information management	geomatics	polar orbiting satellite
building information modeling	geopositioning	precision agriculture
building information modelling	geostationary satellites	property developer data
cadaster	geo-traceability/ geotraceability	property development information
cadastral	geovation	proximity marketing
cadastral surveying	gps data	radar
cadastre	gps systems	radio-frequency identification
cartograph	gps technology	real-time data sensor
cartography	gps tracking	remote sensing
city plans	gps tracking devices	route optimisation
computer aided cartography	gps-enabled	routing optimisation
digital cartography	indoor positioning	satellite data
digital map	land survey	satellite imagery
digital mapping	lidar	smart sensor
earth observation	location data	soil mapping
environmental mapping	location information	soil testing
geobehavioural / geo-behavioural / geo - behavioural	location intelligence	spatial analysis
geobusiness	location tracking	spatial awareness
geocaching	location-based marketing	spatial data
geoconsulting / geo-consulting / geo - consulting	location-based service	spatial resolution
geodata / geo-data / geo - data / geo data	location-based technology	topographic map
geo-demographics / geodemographics / geo - demographics	low earth orbit	topography
geodesy	map data	track location
geodetic	mapping data	tracking system
geo-encoded	mapping software	urban planning

Source: Frontier

Tier 3 rule

- Regardless of the sector in which it operates, if a company description contains at least two search terms that are Tier 3 terms, then it was identified as a relevant company. These Tier 3 terms are more generic than the Tier 2 list and include terms like 3D visualisation and drones. However, multiple relevant terms are needed within a company's description before it can be included as a "core" geospatial company. Some terms are very

similar to each other and so we grouped these similar ones together so that no two terms from the same grouping would be counted (we term these groupings "buckets"). These are shown in Figure 51 below. For instance: "***map***", "***map data***", "***mapping data***" and "***mapping software***" are considered as one group.

Figure 49 Tier 3 search terms

Search terms		
3D visualisation	geotechnical/ geo-technical / geo - technical	navigation devices
3D mapping	Geosoft	navigation equipment
aerial photography	geostationary satellites	off-shore exploration
arc GIS	geotechnical/ geo-technical / geo - technical	oil exploration
atmospheric research	geo-traceability/ geotraceability	Oracle Spatial
bathymetric	geovation	Ordnance survey data
city plans	Geowise	photogrammetry
digital elevation models	GLONASS	post GIS
DigitalGlobe	GNSS	precision agriculture
drones	hexagon	precision-GNSS
earth observation	hydrographic survey	proptech
environmental data	indoor positioning	proximity marketing
Esri	internet of things	qgis
gas exploration	journey planning	radar
geobehavioural / geo-behavioural / geo - behavioural	Landsat	radio-frequency identification
geobusiness	lidar	satellite data
geocaching	location data	satellite imagery
geoconsulting / geo-consulting / geo - consulting	location information	seabed
geodata / geo-data / geo - data / geo data	location intelligence	simultaneous localisation and mapping
geo-demographics / geodemographics / geo - demographics	location tracking	smart city
geodesy	location-based marketing	soil mapping
geodetic	location-based service	soil testing
geo-encoded	location-based technology	structural mapping
geo-fencing	maritime surveillance	telematics
geointelligence / geo-intelligence / geo - intelligence	maritime survey	telemetry
geolocation / geo-location / geo - location	meteorology	track location
geomatics	mineral analysis	tracking system
geophysical survey	mineral exploration	unmanned aerial systems

Search terms		
geopositioning	mobile mapping	urban planning
geostationary satellites	navigation charts	

Source: Frontier

In Figure 50 below we present the groupings for Tier 3 search terms (which we called "buckets"): terms in the same group only count towards one of the two terms needed to be a Tier 3 company. For example, "***aerial survey***" and "***aerial surveying***" would only be counted as one term.

Figure 50 Similar terms grouped together in buckets for Tier 3

aerial survey aerial surveying	gps tracking gps tracking devices
asset mapping asset tracking	gps data gps-enabled
automatic vehicle location autonomous system autonomous vehicle autonomous vessel	gps systems indoor positioning indoor mapping location analytics
building information management building information modelling 3d mapping	marine survey bathymetric surveying coastal mapping
BIM building information modeling	oceanography oceanographic
cadaster cadastre cadastral cadastral surveying	off-shore surveying multibeam ROV remote operated vehicle
cartograph cartography	physical map area map
digital aided cartography computer aided cartography	property developer data property development information
map map data mapping data	remote sensing smart sensor real-time data sensor
mapping software	route optimisation routing optimisation
digital map digital mapping	spatial analysis spatial awareness spatial data spatial resolution
electronic navigation charts precision positioning	
geographic data geographic information geographical information	surveying surveyors
geographic information system geographical information system	land survey
	topographic map topography

Source: Frontier

B.2 Specific inclusion and exclusion rules

We set specific inclusion and exclusion rules in Tiers 2 and 3 to reduce the incidence of false positives (incorrectly including a non-geospatial or non-core geospatial company). We found that even with a specific sector and search word combination for Tier 2, or a requirement of at least two search terms from different buckets for Tier 3, some of the companies we identified were false positives: identified by our methodology but not fitting the definition of a "core" geospatial company.

For instance, we found that company descriptions containing the phrase "***journey planning***" led to mostly false positives with companies which talked about the

career journeys of key individuals or success journey planning - not in the locational sense. We therefore set a specific inclusion rule for this to be included only if the description did not contain "***customer journey planning***", "***user journey planning***" or "***executive minibus service***".

Some inclusion and exclusion rules are specific to the different datasets. It is not possible to search the UKRI platform with compound search terms: searching for 3D visualisation brings up all results that have 3D and visualisation anywhere in the description rather than as the set phrase "3D visualisation". Therefore, the UKRI data 3D visualisation was in the Tier 3 bucket with 3D mapping (and other BIM-related search terms). Also, as UKRI data does not have sectors, there were additional exclusion rules to remove irrelevant healthcare projects and lead companies that are public research bodies.

B.3 Validation process

To ensure a robust and comprehensive final sample, our methodology had a number of quality assurance forms.

Verification

- The search algorithm and extraction method was consistently reviewed for all four platforms, Beauhurst, glass.ai, Bloomberg and UKRI. Where necessary, exclusion rules were implemented for further refinement of search results.
  - There were multiple iterations of results with glass.ai where Frontier and the Commission reviewed samples and adjusted the search algorithm accordingly. These changes were applied across all datasets for consistency.
- The artificial intelligence technology of the glass.ai platform, in particular, can assure a 95% confidence level in company registration number matching.
- The de-duplication of firms within the datasets, merging and tiering algorithms were independently quality assured within Frontier.
- The final step of the quality assurance process included checking the final sample against lists of known companies active in the geospatial ecosystem.

Validation

- The selection of relevant search terms and sectors was tested and sense-checked with a number of experts from the Geospatial Commission. This process was ongoing and iterative, and fed back into the final methodology. Further validation of search terms and sectors was provided from Frontier's qualitative engagement with industry experts.

B.3.1 The random sampling approach was a stepped approach

This was a core part of our validation process.

The random sampling approach was broken down into steps. Note, as the number of core geospatial companies identified from the Bloomberg dataset were very few, all identified companies from this dataset were checked. The random sampling approach applied therefore for the Beauhurst, glass.ai and UKRI data sets.

Figure 51 Stepped approach

Source: Frontier

1) 10% random sample of Tier 1

- Our method was to check 10% of Tier 1 results across each dataset, covering a minimum of 5 companies for each dataset.
- However, as there were relatively few numbers of Tier 1 results, we checked all of these.
- We looked for 90% confidence in correctly identified companies.
- If false positives were identified and concentrated in specific granular sectors, we reviewed a larger sample from these to:
  - Conduct a deep-dive analysis where 3 or more false positives were in the same granular sector
  - Identify problematic sectors for particular focus in step 2.

2a) 10% random sample of Tier 2

- This involved assessing at least a 10% random sample of Beauhurst "Top-Level Sectors" and glass.ai sectors. A minimum of 5 companies were checked and, if a sector grouping contained 5 or fewer companies, all companies were checked. For completeness, in some cases if there were 30 or fewer companies, all were checked.
- Since sector information is unavailable in the UKRI dataset, as a conservative measure all Tier 2 search terms were upgraded to Tier 1 treatment. As such, a 10% sample of all UKRI Tier 2 and 3 firms were assessed (minimum 5 company check applies).
  - As sector description was also unavailable, UKRI firms were assessed through a combination of searching the company website and reading the project title and abstract. As described in B.2 we did some additional and separate cleaning of UKRI lead organisations and project titles to remove some of the false positives that sector-based rules would have addressed.
- We looked for 90% confidence in correctly identified core geospatial companies within each sector. Where this was not satisfied, we conducted a deep-dive analysis into company descriptions to identify any systematic reasons why irrelevant firms were being picked up.
  - For Beauhurst companies, conducted a deep-dive analysis into low-level sector headings within the Top-Level category of interest.

2b) 10% random sample of Tier 3

- We repeated the steps above and reviewed a 10% sample of Tier 3 firms,
- We reviewed 10% of the sectors that were present in Tier 3 companies. While Tier 3 did not have the sector and search term requirement that Tier 2 did, we still reviewed the results by sector to check if we needed to make specific sector inclusion or exclusion rules for false positives in Tier 3.

3) Repeat to check for excluded firms

- We repeated step 2 with the raw extracts of Beauhurst, Bloomberg and UKRI data separately. This checked that the tiering rules did not exclude any correctly identified companies.
- Tier 1 did not have any excluded companies as by default all companies with "***geospatial***" in the description were included.
- The glass.ai data shared with us were the tiered results, rather than the raw extract as the validation was already conducted on an iterative basis with the glass.ai team, and so we had fairly high confidence in to appropriateness of our results (given checks conducted in steps 1 and 2). We therefore did not conduct additional reviews to check the glass.ai data for excluded relevant firms.

4) Review top 10% by most recent turnover and equity funding

- We filtered the top 10% by turnover in each dataset: Bloomberg, Beauhurst, glass.ai and FAME data. We also reviewed the top 10% by equity investment for Beauhurst companies.
  - N.B. All Bloomberg firms, which likely contain such high-turnover firms, were already checked by this point.
- We looked for 100% confidence in correctly identified companies for high-turnover companies.
  - This is where we made the decision to exclude UKRI lead organisations found only in UKRI data with turnover above £50 million from the list of core companies (the underlying projects were still included).

Final review

The validation process led to some changes to the search terms and rules. These were briefly iterated with glass.ai with samples of the companies identified by the new search terms checked and further slight amendments were made.

Once the final dataset had been provided by glass.ai and the additional search terms run through Bloomberg, Beauhurst and UKRI, we sampled the new rules and terms from the consolidated dataset to ensure the changes were leading to the right results. This was a light-touch exercise, but we ensured all companies positively identified as relevant from the validation were still included and those already identified as not relevant were still excluded.

B.4 Sources for the companies identified in other research

Other geospatial market reports and industry sources had already identified lists of companies before our work. We created a collated list of companies from these datasets to supplement our search term method. We did not include all these in our list of companies as they did not all meet our core definition.

Figure 52 List of additional sources which we validated our list of companies against

Company list source
Geospatial Commission Future Technologies Review[133]
Geospatial Commission Call for Evidence respondents[134]
UK Space Capabilities Catalogue[135]
GeoBuiz 2019 Geospatial Industry Outlook and Readiness Index[136]
Open Geospatial Consortium Member List[137]
NESTA drones report[138]
Commercial partner lists from relevant Partner Bodies
Market study roundtable attendees with techUK
Knowledge Transfer Network - Geospatial Insights Special Interest Group internal company analysis
Geovation cohort companies

Source: Frontier

B.5 Matching companies across multiple datasets

Some of the companies we identified were found in multiple datasets and therefore we needed to ensure that we did not double count these when we consolidated the datasets.

Our stepped process for checking for matches and merging was:

1. Companies House number match. This was the preferred method of matching as it provides the most accurate match.
2. Cleaned name match. This was the second choice of matching. The company names in each dataset were cleaned to remove all spaces, to be all in upper case and to remove company structures such as LTD. We also removed words such as *institute*, *holdings* and *UK* at the end of names as this improved the matching ability.
3. Fuzzy name matching. This was the third option for matching. We conducted fuzzy matching on the cleaned names and set some additional rules:

[133] https://www.gov.uk/government/publications/future-technologies-review
[134] https://www.gov.uk/government/publications/geospatial-commission-call-for-evidence-responses
[135] https://issuu.com/satappscatapult/docs/capabilities_catalougue_v40
[136] https://geobuiz.com/geobuiz-report-2019/
[137] https://www.ogc.org/ogc/members
[138] https://www.nesta.org.uk/report/flying-high-challenge-future-of-drone-technology-in-uk-cities/

a. Names had to be over 5 characters (avoids technically similar names that are practically different e.g. AAB and AAZ)
b. Levenshtein distance of 2 (the 5+ characters and distance of 2 came through some manual tuning).

If all three steps did not give a match, then we took this to mean that this was a new company to add to the dataset.

B.6 Beauhurst tracking triggers

The Beauhurst tracking triggers are designed to "signal high-growth or ambition".[139] A company is tracked if it met at least one of the triggers since 2011, set out in the following table.

Figure 53 Beauhurst tracking triggers

Tracking trigger	Criteria for trigger
Secured equity investment	▪ Disclosed publicly or directly to Beauhurst that equity investment has been secured; or ▪ See evidence of equity investment in Companies House filings.
Secured venture debt (loan)	The presence of one or more of: ▪ Mechanisms for the lender to share more of the upside than simply charging interest; ▪ Mechanisms for the lender to share more of the downside than simply accepting default risk; or ▪ Borrower company would typically not be eligible for a loan on the basis of being too young or unprofitable.
Underwent management buyout or buyin (MBO/MBI)	▪ Incumbent on incoming management taking a stake in a company; and ▪ A majority stake is taken in that company through that transaction Minority acquisitions are not covered.
Attended a selected accelerator programme	Accelerator programmes validate the ambition and growth of participating companies. They must meet all of: ▪ Start and finish data; ▪ Structure (one of syllabus, milestones, mandatory events); ▪ Competitive application process; and ▪ No or low attendance fees.
Has been or is a scale up (10% or 20%)	The 10% trigger is met when it meets the OECD/Eurostat definition of "high-growth enterprise": annualised average growth rate of at least 10% in turnover or headcount over three accounting years. There are two pre-requisites: ▪ 10 or more employees; and ▪ Growth would still be 10% if growth directly attributable to the acquisition of other companies. Companies which meet the 20% trigger are a subset of the 10% companies. Beauhurst can only track "visible scaleups" where the relevant data has been filed. Companies do not need to file turnover or employee numbers if they meet two of the below: ▪ Annual turnover of £10.2 million or less; ▪ Balance sheet total of £5.1 million or less; or ▪ No more than 50 employees on average.

[139] https://platform.beauhurst.com/help/faq#what-does-tracked-mean-and-what-is-the-tracking-process

Tracking trigger	Criteria for trigger
Spun out of an academic institution	▪ Company set up to exploit intellectual property developed by a recognised UK university And one of: ▪ University owns IP that it has licensed to the company; ▪ University owns shares in the company; or ▪ It has the right to purchase shares at a later date.
Was featured in a selected high-growth list	Eligible high-growth lists must have: ▪ Main focus is high growth, high innovation and/or ambition; ▪ Competitive and selective application process; and ▪ No fee is required to be featured.
Accepted a large innovation grant	Companies which have formally accepted a large grant offer for a specific project. ▪ Large is £100k+ or €100k+ and it must all be received by an individual company for a single project; ▪ Primary focus on "new to the market" innovation; and ▪ Formal acceptance may lag awarding body grants.

Source: *https://platform.beauhurst.com/help/faq#what-are-the-beauhurst-tracking-triggers*

Note: *Beauhurst evidences that around 70% of equity fundraisings are undisclosed and they find these through their proprietary technology.*

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