THE CONNECTED PLACES MARKET IN THE UK

A report prepared for the Department for Digital, Culture, Media and Sport

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Confidential

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EXECUTIVE SUMMARY

Frontier Economics was commissioned by the Department for Digital, Culture, Media and Sport (DCMS) to assess the size and characteristics of the Connected Places market in the UK. Our work includes analysis of the demand- and supply-side barriers to the effective functioning of the market, with a particular emphasis on cybersecurity.

The Connected Places market uses digital technology (systems of sensors, networks and applications) to build digital connections between physical places. When used in urban locations, these can also be described as "smart city" services. The Connected Places market as defined in this report includes products and services within the following "domains" or "verticals":

- Transport and mobility (including, for example: traffic management, smart highways, connected and autonomous vehicles, sharing of "micromobility" vehicles such as electric bicycles and scooters);
- Built environment (including, for example: residential and commercial "smart" buildings, digital planning, AI-assisted planning);
- Public realm and natural environment (including, for example: environmental monitoring such as air and water quality);
- Utilities and infrastructure (including, for example: smart meters, smart local energy systems, predictive and preventative maintenance);
- Health and wellbeing (including, for example, use of digital technology in delivering social care and assisted living, remote healthcare); and
- Decision making in local government and related institutions (using data analytics and digital solutions to aid decision making).

This study aims to help DCMS in making informed policy choices regarding this market, to support the development of the market and to ensure the security, resilience and inclusivity of Connected Places.

Our approach

We have collected and analysed new data on suppliers in the Connected Places ecosystem, supplemented with qualitative interviews with 20 organisations, including:

- Seventeen suppliers active in the UK (comprising six large companies, nine small and medium-sized enterprises and two research organisations); and
- Three "demand-side" organisations that purchase Connected Places products and services.

The objective of our qualitative interviews was to investigate the suppliers' role in the market, their expectations, and perceptions around the drivers of and barriers to the growth and security of Connected Places. We did not aim to collect statistically representative evidence, which would not be achievable with a sample size of 20 organisations, but rather to provide a rich picture of the relevant issues from each interview. However, our selection of interviewees achieved a broad coverage of the domains and technologies in the Connected Places market.

Market size and composition

Market size

We have identified 1,078 companies active in supplying products and services in the UK Connected Places market. Some of them do all their business in the Connected Places ecosystem while others are active in other markets too. The latter group includes, for example, several very large companies in the Information Technology, Engineering, Construction and Utilities sectors.

We estimate that there are between 24,000 and 45,000 employees supplying Connected Places products and services in the UK; our best estimate is around 37,000. Among these 37,000 people, around 50% are employed by large companies. We estimate that Connected Places businesses generated £3.3bn-£3.6bn in Gross Value Added in 2020.[1]

These figures suggest that Connected Places is a relatively small market compared with the overall UK digital sector. But its size is broadly in line, if somewhat smaller, than more specialised and novel subsectors within the UK digital economy, such as cybersecurity and geospatial data services.[2]

Compared with six other selected countries, we find that the UK Connected Places market is smaller than that of the United States but larger than in Germany, Spain, Canada, Sweden and Singapore, both in terms of the number of companies and employment. The number of Connected Places jobs as a proportion of overall employment is very similar in the UK, US, Germany, and Spain; it is higher in the smaller economies analysed in this report (Canada, Sweden and Singapore). A relatively large proportion of the UK's Connected Places suppliers and employees operate in the "Built environment" and "Critical infrastructure and utilities" domains, compared to other countries.

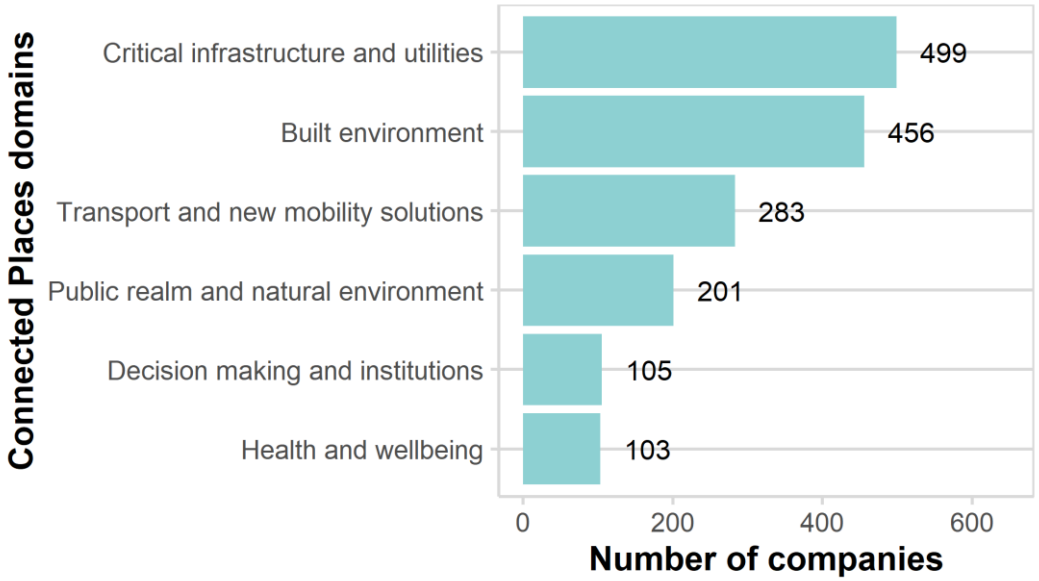
Market composition by domain

Figure 1 shows the number of companies active in the UK Connected Places market by domain. We found that 75% of Connected Places firms are concentrated in three domains: "Critical infrastructure and utilities", "Built environment" and "Transport and new mobility solutions". "Decision making and institutions" and "Health and wellbeing" are the smallest domains, numbering only 105 and 103 companies, respectively.

[1] This figure is reached by multiplying the employment figure (37,000) by an estimate of the GVA per worker typically generated by digital companies in the industrial sectors relevant to Connected Places. A detailed description of this calculation is provided in Annex A.

[2] Cybersecurity market: 46,700 employees in the UK; Geospatial data market: 115,000 employees in the UK. Sources: Cybersecurity Sector analysis 2021; Frontier Economics (2020), "Geospatial Data market review".

Figure 1 Number of Connected Places suppliers in the UK by domain



Source: Frontier Economics analysis of Glass.ai data

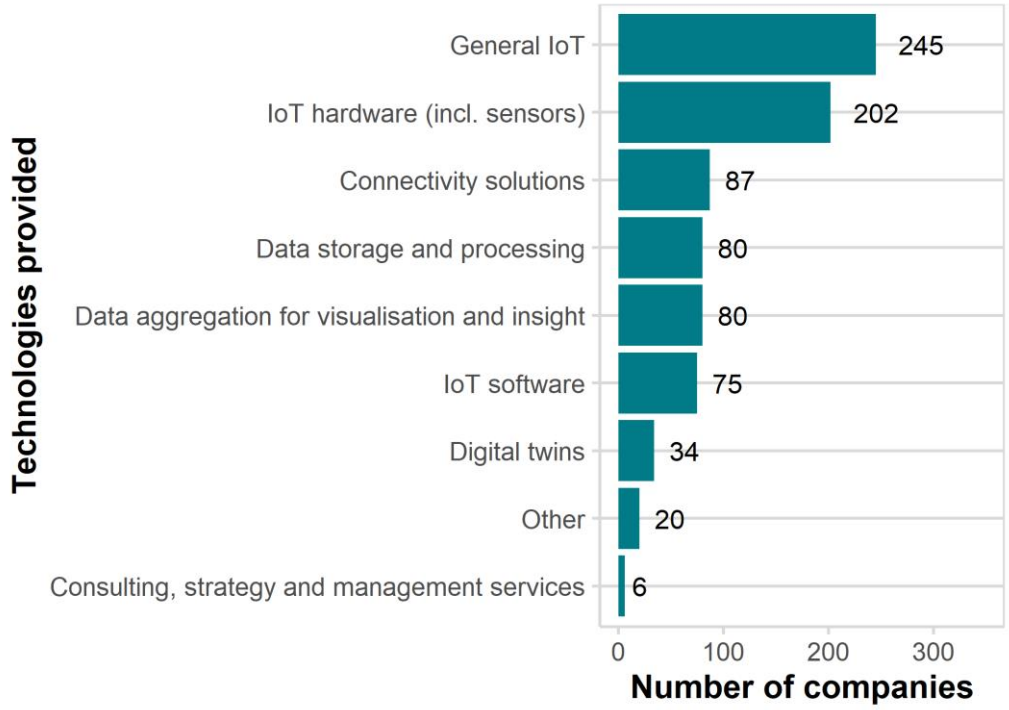
Note: Total sums to more than 1,078 companies as several companies are active in more than one domain.

Market composition by technology

Figure 2 shows a breakdown of companies' own descriptions of their offering. Of the 1,078 suppliers in our dataset, 245 used "general IoT" terms, such as "Internet of Things" (IoT) or "IoT technologies", to describe their offering.[3] Some were more specific, saying that they provide IoT hardware (202 companies offering, for example, "IoT sensors", "drones", "endpoint devices") or IoT software (75 companies that mentioned "IoT software" or, for example, "IoT platforms").

[3] The term "Internet of Things" is used to refer to networks of devices across a spectrum of applications, from the smallest connected sensors and devices to large-scale platforms that can be deployed with physical infrastructure. Source: Royal Academy of Engineering (2018), "Internet of Things – realising the potential of a trusted smart world".

Figure 2 Number of Connected Places suppliers in the UK by technology provided



Source: *Frontier Economics analysis of Glass.ai data*

Note: *Excludes 657 out of 1,078 companies that did not match any technology-related search terms. A "digital twin" is defined as is a digital copy of a real-life asset, process or system.*[4]

Market composition by firm size

Based on our data, we find that 87% of Connected Places suppliers are classified as Small and Medium Enterprises (SMEs) and 13% are large companies. As context, only 1% of all UK businesses and 0.3% in the ICT sector are large companies, so this group is over-represented in Connected Places.[5] This is similar to other digital sectors in the UK, for example cybersecurity and geospatial data.

Our qualitative interviews indicate that large firms and SMEs often offer different products and services, which can be complementary. Large firms are more likely to offer end clients (e.g. local authorities) integrated solutions covering all aspects of the technology value chain, from data collection through sensors to data analytics and consulting. In doing so, large firms frequently rely on SMEs to provide specific products or services within that value chain. This can allow innovative products developed by SMEs to be embedded into digital packages for end clients. Conversely, SMEs at times turn to large firms for some services, in particular cloud storage and computing.

[4] Source: Royal Academy of Engineering (2018), "Internet of Things – realising the potential of a trusted smart world".

[5] Source for data on all UK businesses: Office for National Statistics, Business Population Estimates 2021.

International presence of firms active in the UK

Our data shows that 19% of all Connected Places suppliers do business outside the UK, serving a total of 73 countries. They are most active in the US (117 companies), with Germany a distant second (30 firms). Eighteen companies have a presence in China, of which four are Chinese-owned.

Functioning of the market

Through our interviews, we have identified the following issues that may warrant policy intervention to support the growth of a secure Connected Places ecosystem.

Interoperability

Large suppliers identified a lack of interoperability between different devices and technologies as a significant barrier to the development of Connected Places. However, this was less of an issue for the SMEs we spoke with, many of which are in the process of bringing new products to market and have not (yet) considered interoperability.

These findings suggest that there are opportunities for policy to support the Connected Places market via additional guidance and standards for interoperability. However, this may be less relevant for those parts of the market where new technologies are still evolving, for example autonomous vehicles. Therefore, a domain- or technology-specific approach to addressing interoperability issues may be more valuable than an ecosystem-wide approach. This could be further explored in additional research on the issue.

Additional interoperability would be helpful for the development of integrated solutions, but connecting more devices and systems to each other may create vulnerabilities. Therefore, guidance and standards on interoperability would benefit from including cybersecurity considerations.

Data sharing

All stakeholders highlighted data sharing as a significant barrier to market innovation and growth. There appear to be three key issues:

- Commercial value of data: several stakeholders (large firms and SMEs) gave examples of businesses being concerned that releasing their data in a connected system would lead to a loss of competitive advantage.
- Sensitive data: private and public sector organisations not sharing potentially sensitive data.
- Liability if things go wrong: public and private sector data providers are hesitant to share data if, in case of mishaps, they could be held liable for causing an accident or serious error and thus be exposed to potentially significant financial costs.

This suggests that to support data sharing it would be useful to help suppliers and customers better understand who should own the data ingested by and/or

generated by Connected Places, how risks of negative consequences from data use can be mitigated, and who should be liable for those consequences.

There were mixed views among the organisations we canvassed about whether and how standards for data sharing could help; some advocated a more centralised approach, but others were against.

It would be useful to explore through further research whether security concerns specifically are preventing data sharing, and to what extent interventions that bolster confidence in the cybersecurity of Connected Places would lead to greater sharing. Conversely, interventions that aim to boost data sharing may have the unintended consequence of increasing the vulnerability of Connected Places.

Customers' and suppliers' perceptions of cybersecurity risks

The suppliers we engaged with highlighted the importance of effective monitoring of and reaction to security threats in Connected Places. But they felt their customers focus too much on the prevention of security incidents, and on protecting front-end devices (e.g. security cameras), rather than on the back end of systems (data flows, data storage).

Some suppliers also felt that Connected Places would benefit from integrating cybersecurity considerations more closely into overall project design rather than treating it as a separate matter. Part of the reason for this appears to be, according to suppliers, a lack of technical skills on the demand side (described below).

Most of the SMEs we interviewed did not consider cybersecurity issues to be directly relevant to their business – at least not yet. It is possible that this is entirely explained by the type of work they do, and/or by the stage of development of their technology. However, it would be useful to gather additional evidence to understand whether some SMEs are under-estimating cybersecurity risks and, in particular, what consideration they give to cybersecurity when products are used at scale.

Technical skills

A majority of the organisations we engaged with felt that a lack of technical knowledge among public sector customers results in public sector Connected Places projects not being specified effectively. In particular, a shortcoming they identified is a lack of knowledge of how to best invest in the security of Connected Places.

Several participants felt that existing guidance on cybersecurity is useful but not sufficient to address gaps in knowledge. There were mixed views on whether additional guidance would be helpful or other approaches would be preferable.

The high cost of accessing relevant data science skills for both Connected Places suppliers and customers was widely viewed as impeding the development of the market.

This suggests that while deeper understanding of Connected Places projects and related cybersecurity questions would be helpful, Connected Places customers might not find it easy to acquire such knowledge by recruiting new staff or improving the skills of their current workforce. Therefore, policy interventions to

support the acquisition of technical and cybersecurity skills, or to provide this knowledge directly, may be beneficial. Further research could investigate the likely benefits and costs of potential courses of action. Options for direct provision could include creating a central expert/commissioning support unit to work with local authorities and other public sector organisations on Connected Places projects with a relatively high security risk.

1 INTRODUCTION

1.1 Objectives of this study

The Department for Digital, Culture, Media and Sport (DCMS) commissioned Frontier Economics to assess the size and characteristics of the Connected Places market in the UK.

The market uses digital technology (systems of sensors, networks and applications) to build digital connections between physical places. The data that is collected is used to create and improve services in the built environment, including the operation of transport, buildings, utilities, environment, infrastructure and public services. When used in urban locations, these services can also be described as "smart city" services.

Connected Places have the potential to generate significant economic and social benefits to the UK, from reducing traffic congestion to achieving greater energy efficiency and better supporting vulnerable individuals.[6] As such, Connected Places can contribute to several public policy objectives, as reflected for example in DCMS's top 10 tech priorities. These include unlocking the power of data in the economy, supporting economic growth across the UK and aiding the transition to a net zero economy.

However, there are also risks. The use of digital technology for critical functions makes Connected Places systems attractive targets for a range of threat actors; significant damage could be done if these systems are compromised.[7] Realising the benefits of digital technologies while mitigating the risks of adopting them is one of the goals identified in the Government's most recent Integrated Review of Security, Defence, Development and Foreign Policy. To support local authorities in ensuring the security of Connected Places and related infrastructure, the National Cybersecurity Centre published a set of Connected Places Cybersecurity Principles in May 2021.

This study aims to support DCMS in making informed policy choices regarding this market, to support its development and to ensure the security, resilience and inclusivity of Connected Places. This includes:

- Identifying suppliers of Connected Places products and services operating in the UK, segmenting the market appropriately in terms of:
  - Technology/service provided;
  - Domain focus area (e.g. Transport and mobility versus Built environment);
- Identifying the size of these suppliers and their international presence;
- Valuing the overall size of the UK Connected Places market;

[6] As discussed for example in McKinsey (2018), "Smart Cities: Digital Solutions for a More Livable Future" and OECD (2020) "Smart Cities and Inclusive Growth".

[7] Source: National Centre for Cyber Security.

- Comparing the UK Connected Places market with six other countries (Canada, Germany, Spain, Singapore, Sweden, US) and with three other digital sectors; and
- Assessing the potential barriers to and drivers of the development of Connected Places in the UK, with a particular focus on cybersecurity.

1.2 Our approach

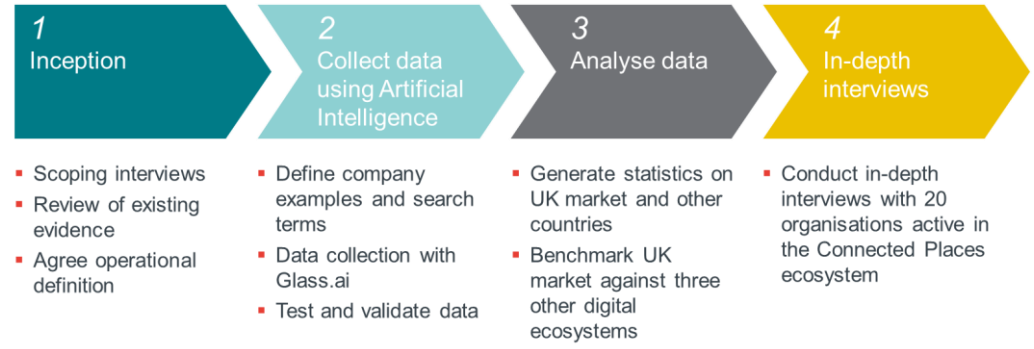
Our approach consists of four phases of work, described in Figure 3 below.

In the first phase, we used scoping interviews and a rapid review of evidence to generate an operational definition of the Connected Places market. This is because there is no standard industrial classification that can be used to gauge activity relevant to Connected Places. A definition was required to determine how Connected Places suppliers should be identified and measured (in phases 2 and 3) and which organisations would be relevant for our in-depth interviews (phase 4).

In phases 2 and 3, we identified companies active as Connected Places suppliers in the UK and in the six comparator countries. We also collected and analysed data on their areas of activity, size and international presence.

In phase 4, we used in-depth interviews to gather additional information on larger companies in the market. We also canvassed views on the barriers to and drivers of growth and security of Connected Places in the UK.

Figure 3 Summary of approach



Source: Frontier Economics

1.2.1 Operational definition of Connected Places

As part of this project, we developed an operational definition of Connected Places in order to identify which companies should be counted as part of the market by Glass.ai's Artificial Intelligence (AI) system. Our definition included terms and expressions that Connected Places suppliers use to describe their activity as well as known examples of Connected Places suppliers. These terms, expressions and examples were used as inputs into the AI system. This operational definition consists of:

- A list of domains ("verticals") in which Connected Places solutions can be applied;

- A list of technologies/technological solutions ("horizontals") that can be applied in Connected Places;
- An indicative list of outcomes that can be achieved or avoided by making places more connected.

Our operational definition does not aim to provide a universally agreed, exhaustive description of Connected Places. Definitions of key terms used in this and following sections of the report are provided in the Glossary.

Domains

We use **Connected Places domains** to refer to the different areas in which Connected Places solutions can be applied:

- Transport and mobility (including, for example: traffic management, smart highways, connected and autonomous vehicles, the sharing of "micromobility" vehicles such as electric bicycles and scooters);
- Built environment (including, for example: residential and commercial "smart" buildings, digital planning, AI-assisted planning);
- Public realm and natural environment (including, for example: environmental monitoring such as air and water quality);
- Utilities and infrastructure (including, for example: smart meters, smart local energy system, predictive and preventative maintenance);
- Health and wellbeing (including, for example, use of digital technology in delivering social care and assisted living, remote healthcare); and
- Decision making in local government and related institutions (using data analytics and digital solutions to inform decision making).

Technologies

The **Connected Places technologies** that deliver Connected Places include:

- Internet of Things (IoT) hardware (including actuators, edge devices, sensors, embedded devices and chips, smart devices, connected devices, readers, gateways and drones);
- Internet of Things (IoT) software (including applications, modules, platforms, software, products and solutions);
- Connectivity solutions (such as 5G, solutions for wide area networks, mesh networks, communication systems (such as vehicle-to-infrastructure, vehicle-to-vehicle, IoT networks);
- Data storage and processing solutions (such as cloud integration and platforms, data exchange, integration and sharing, edge and fog computing, location intelligence); and
- Data aggregation for visualisation and insight (including advanced visualisation, data analytics, integrated analytics and Digital Twins). [8]

[8] Virtual representation of real-world objects, processes, behaviours and relationships.

Outcomes

The outcomes that can be enabled through Connected Places technologies are varied and wide-ranging. They include, among others:

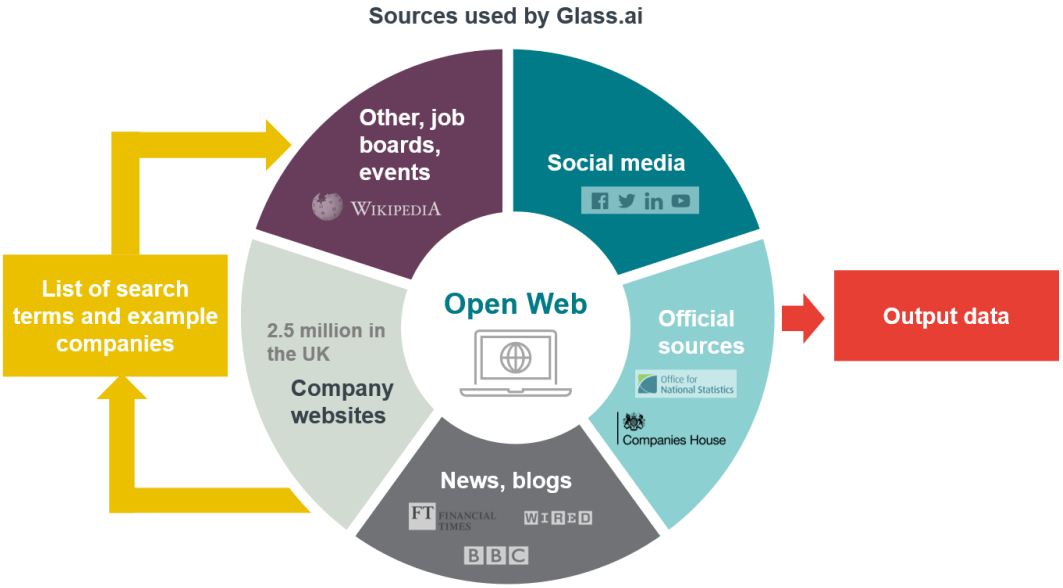
- Short-term outcomes: for example, better management and maintenance of infrastructure; improved monitoring of air quality, temperature and other environmental conditions in buildings and in public spaces;
- Medium-term outcomes: for example, reduced travel times, improved air quality, lower consumption of resources (energy, water), fewer accidents, fewer security incidents, lower emissions of CO2 and other environmentally harmful substances;
- Long-term outcomes: for example, improved health and wellbeing, the sustainability and resilience of Connected Places, civic engagement, economic growth.

1.2.2 Quantitative data collection and analysis

Our approach to data collection relies on collaboration with Glass.ai, which provides an AI algorithm that reads the web using a proprietary language. The AI technology understands written language and reads millions of web pages spanning companies, organisations, news, social media, event notices and academic and official sources. Using the search terms that form part of our operational definition, it can identify companies that provide Connected Places products and services and gather data on their activities (employment, revenues).

At a high level, this approach is illustrated in Figure 4 below.

Figure 4 Illustration of Glass.ai approach



Source: Frontier Economics

The key advantage of this approach is that it can identify large numbers of companies efficiently, with limited manual input, where classifications in existing databases are not sufficiently detailed. For example, it would be very challenging

to identify Connected Places companies from large firm-level databases such as the Office for National Statistics' Business Structure Database, or FAME.[9] This is because the only indication in these databases about the markets in which a company is active is to be found in its Standard Industrial Classification (SIC) code. To date, there are no SIC codes specific to Connected Places. Other sources that provide more fine-grained industry descriptions, such as Beauhurst or Venture Capital investment databases (e.g. Crunchbase, Dealroom), focus specifically on fast-growing, generally small companies, whereas Glass.ai captures information on companies of all sizes and regardless of their recent growth.

The main limitations of this approach are the following:

- The approach relies on web sources, primarily companies' websites. Some organisations may be active in the Connected Places market but may not have an online presence or may not describe their Connected Places activity online.
- In a large majority of cases, data on a company's staffing numbers is sourced from its profile on LinkedIn, the professional networking service. This may not always be a precise measure of a firm's employment overall; and if a company is active in several countries, it may not be a precise measure of how many jobs it sustains in the UK . However, by using LinkedIn information Glass.ai was able to provide workforce data for around 80% of the Connected Places suppliers we identified. For context, only around 10% of these companies report job numbers in their accounts available from Companies House, and data on employment is typically available for only around one-third of companies in databases such as Crunchbase or Beauhurst.

Defining the search strategy

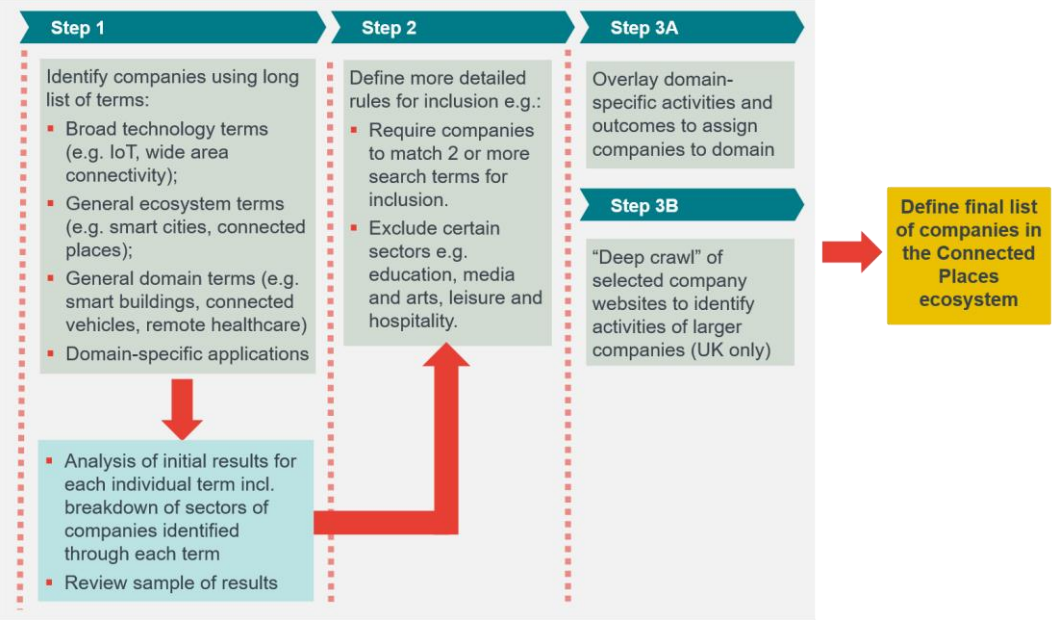
Applying this approach involves using a search strategy tailored to the specific market of interest:

- Generating an initial list of search terms and examples of companies active in the Connected Places market;
- Using this list to generate an initial dataset of companies identified through the AI algorithm;
- Refining the list based on a manual review of a sample of results and the identification of some explicit rules that can improve the quality of results (for example, excluding irrelevant industrial sectors).

Our search strategy is represented in Figure 5 below. A more detailed description is available in Annex A.

[9] A dataset including companies based in the UK and Ireland provided by Bureau Van Djik, a commercial organisation.

Figure 5 Summary of search strategy



Source: Frontier Economics

The Glass.ai approach allows us to identify Connected Places suppliers based on descriptions of what they do on their websites and in other web sources. In some cases, in particular for larger companies, Connected Places activity may be part of a broader offering. To account for this, our strategy also included "deep crawls", that is, in-depth searches on a list of 318 companies identified as likely suppliers from existing Connected Places directories and from our desk research.

Information on Connected Places suppliers' employment is based on data from the companies' accounts, available for larger businesses,[10] and on the number of employees listed on LinkedIn.[11] For large companies, which are active both in Connected Places and other markets, available data sources allow us to identify their overall staffing but do not provide information on how much of their activity is specific to Connected Places.[12] To fill this evidence gap, we used interviews with six large suppliers in phase 4 of the project, described in 1.2.3 below.

We defined and validated our search strategy for the UK data, before applying it to the US, Canada, Germany, Singapore, Spain and Sweden. This involved translating English search terms into German and Spanish. For Singapore and Sweden, where many companies have English-language websites, our search strategy was restricted to English material only.

[10] Small companies with an annual turnover of £10.2m or less, or 50 employees or fewer, are not required to file full annual accounts with Companies House.

[11] Where both sources are available, we use data from company accounts as it is likely to be more accurate than data from LinkedIn. We use employment information from company accounts for 12% of firms in our dataset; for 68% of the total our data is based on LinkedIn.

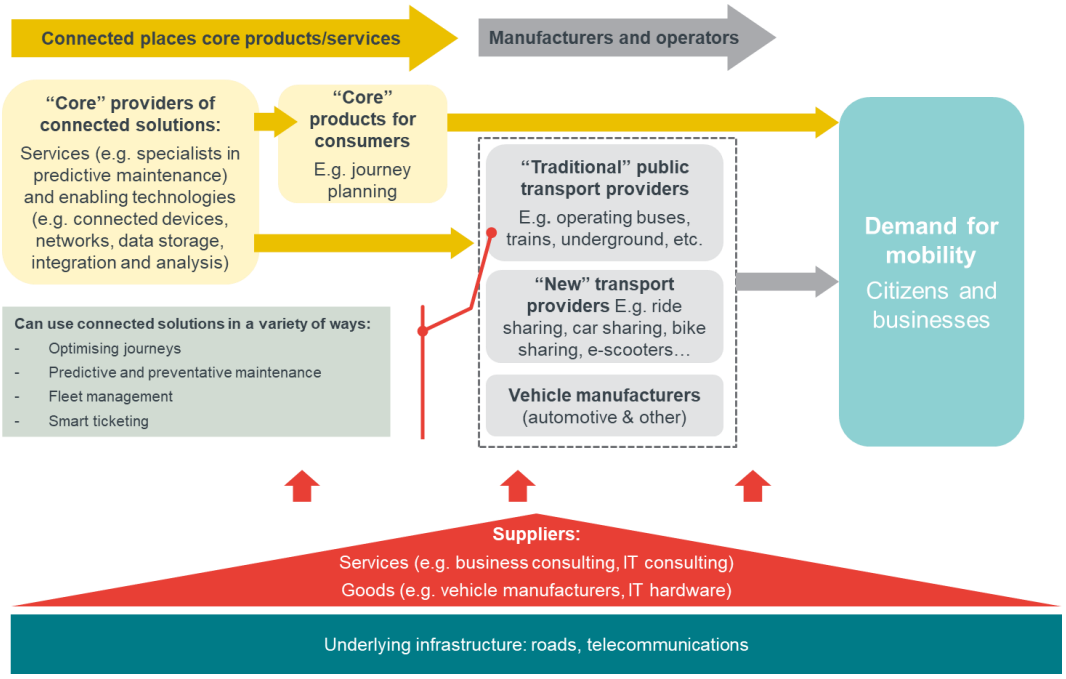
[12] We define large companies as those with more than 250 employees.

Review of search results

As described above, between step 1 and step 2 of our search strategy we reviewed initial results to exclude any false positives (companies that were captured in the data but actually did not meet the criteria) and to find ways to increase the number of relevant companies identified by the algorithm.[13] For this purpose we defined high-level value chains for each domain. This allowed us to define which companies are directly active in providing Connected Places products and services (and so should be included in our dataset), versus firms that operate in the broader supply chain and so should be excluded.

Figure 6 overleaf illustrates this exercise for the mobility component of the Transport and Mobility domain. Our approach is best suited to identifying and measuring the activity of companies defined as "core" providers in the figure below. It does not attempt to capture in its entirety the in-house development of Connected Places solutions by "traditional" providers, such as bus operators or automotive manufacturers. However, they may appear in our search if online data suggests that they have a particularly prominent Connected Places offer - for example, an automotive firm that invests heavily in the development of autonomous vehicles (AVs).

Figure 6 High-level value chain for mobility domain



Source: Frontier Economics

1.2.3 Qualitative interviews

In parallel with our quantitative data collection, we also carried out in-depth interviews with 20 organisations, with two objectives:

1. To gather additional data on the role of large Connected Places companies.

[13] Please see Annex A for further detail on how companies in initial results were classified as relevant or not relevant.

2. To gather information on the functioning of the market, in particular on the provision of cybersecurity; barriers to and drivers of growth; market trends; and the strengths and weaknesses of the UK market compared to other countries.

In doing this, we aimed to provide rich information from each interview, rather than aiming to collect statistically representative evidence, which would not be achievable with a sample size of 20 organisations. However, our selection of interviewees achieved a broad coverage of the domains and technologies in the Connected Places market.

Annex A provides more detail about how we identified participants and the topics we discussed with them.

Figure 7 Organisations participating in qualitative interviews

Organisation category	Number of interviews
Large company active in the market	6
Small company active in the market	9
Public sector customers	2
Private sector customers	1
Researchers	2
Total	**20**

Source: Frontier Economics

1.2.4 Structure of this report

The rest of this report is structured as follows:

- Section 2 shows findings on the size and composition of the UK Connected Places market;
- Section 3 reports findings on the functioning of the market;
- Section 4 compares the UK Connected Places market with other countries and digital sectors;
- Section 5 concludes; and
- The Glossary provides definitions of key terms used in the report.

2 THE SIZE AND COMPOSITION OF THE UK CONNECTED PLACES MARKET

2.1 Size of the market

We have identified 1,078 companies active in supplying products and services in the UK Connected Places market.[14] Some do business only in the Connected Places ecosystem, while some are active in other markets too. The latter group includes several very large companies in the Information Technology, Engineering, Construction and Utilities sectors.

Assessing Connected Places employment in large firms is quite challenging as they do not break down figures for their workforce by market or technology. The Connected Places ecosystem includes around 100 large companies, but not all their employees will be working on Connected Places activities.[15]

Consequently, we allocate only a small proportion of employees in large companies to Connected Places. We estimate that UK Connected Places suppliers employ between 24,000 and 45,000 people; with our best estimate at around 37,000.[16] The lower end of the range assumes that only 1% of employees in large Connected Places companies work in the Connected Places ecosystem, while the upper end makes a less conservative assumption.[17]

In the following sections of the report we use the best estimate of 37,000 employees except where specified otherwise.[18] Among these 37,000 people, around 50% are employed in large companies active in the Connected Places ecosystem. This assumption influences our estimate of the total size of the Connected Places market, but it has very limited impact on our assessment of its characteristics and composition.[19]

We estimate that Connected Places companies generated £3.3bn-£3.6bn of Gross Value Added (GVA) in 2020, with our best estimate at £3.5bn.[20] Our data includes revenue figures for 10% of the 1,078 Connected Places suppliers, which came to a combined £3.2bn. However, this is not a reliable guide to the total turnover of Connected Places companies as it is based on a small proportion of our sample.

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14 The statistics presented in this section exclude companies that have recently ceased trading according to Companies House and non-commercial organisations (e.g. Connected Places Catapult, Centre For Sustainable Transport, The Smart Ports Alliance) and those identified through external sources (CrunchBase and exhibitors at the UK Smart Business Show) with location information outside the UK.

15 Allocating all employees in large companies to Connected Places would mean grossly overestimating the size of the workforce to be around 1.8m people.

16 This figure includes both full-time and part-time employees.

17 The upper range assumes a 1% adjustment for large companies in the 99th percentile, 5% for large companies between the 95th and 99th percentile, 10% for large companies between the 90th and 95th percentile, and 50% for large companies below the 90th percentile.

18 The middle range assumes a 1% adjustment for large companies in the 99th percentile and 5% for other large companies.

19 Employment information is not available for 21% of the 1,078 Connected Places companies; where LinkedIn is used, the company's total workforce may be underestimated as not all employees may be listed on the service. For large companies, this information was validated using UK data extracted from D&B Hoovers.

20 This figure is reached by multiplying the employment figure (37,000) by an estimate of the GVA per worker typically generated by digital companies in the industrial sectors relevant to Connected Places. A detailed description of this calculation is provided in Annex A.

Moreover, the revenues of larger companies are not adjusted to reflect the fact that only part of their activity is in Connected Places.[21]

Overall, these figures suggest that Connected Places is a small market in relation to the overall UK digital sector but is broadly in line, if somewhat smaller, than more specialised and novel subsectors. In section 4.2 we provide a broader comparison of the UK Connected Places market with three other benchmarks (the UK markets for cybersecurity and geospatial data and the European consumer Internet of Things).

Connected Places in the context of the broader UK digital sector

The Connected Places ecosystem as defined in this report includes the provision of digital and digitally enabled goods and services to Connected Places. As such, the vast bulk of the activity falls within the UK's broader digital sector.

The digital sector employed around 1.66m people between October 2019 and September 2020, accounting for 4.9% of all jobs in the UK. In terms of GVA, the sector contributed £148bn to the UK economy in 2019 (constant prices), which was 7.6% of the total. The digital sector contributes as much GVA as the UK's entire manufacturing industry.[22]

The digital sector includes large, established industries, such as telecommunications, and smaller, nascent sectors. Examples of these, among many others, include:

- The cybersecurity sector, with 1,483 companies active in the UK;[23]
- The provision of specialist Artificial Intelligence services. There were around 2,600 AI companies in the UK in 2018, employing some 35,000 people; [24]
- Fintech, one of the largest novel digital sectors, involves the application of digital technology to finance. The UK has 2,500 fintech companies employing 76,000 people, according to the latest data available.[25]

2.1.1 Market size by domain

Figure 8 shows the number of companies by domain. We found that 75% of Connected Places companies are concentrated in three domains: "Critical infrastructure and utilities", "Built environment" and "Transport and new mobility solutions". "Decision making and institutions" and "Health and wellbeing" are the smallest domains, comprising only 105 and 103 companies, respectively.

However, it is worth noting that "Decision making and institutions" is particularly difficult to measure. This domain is not defined by specific technologies (IoT, digital twins) or by applications of these technologies (connected vehicles, predictive maintenance) but rather by the customer base (local authorities, other public bodies, etc.) and high-level objectives (supporting more informed, integrated and responsive decision making; increasing citizen engagement, etc.). However, it is possible that companies active in this domain do not mention their customer base or these high-level objectives on their websites and therefore are not easily

[21] Making this adjustment would be possible in principle, but large organisations participating in our study were not able to estimate the proportion of their revenues accounted for by Connected Places activity.

[22] Source: DCMS sectors economic estimates.

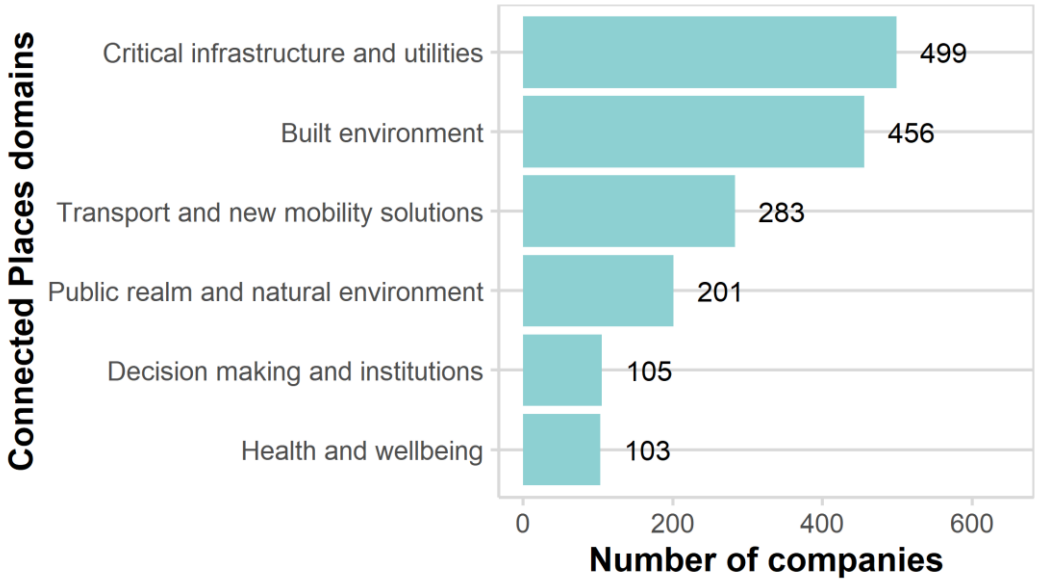
[23] Source: UK Cybersecurity Sectoral Analysis 2021

[24] Source: UK Artificial Intelligence Analysis 2020

[25] Source: UK Fintech State of the Nation

identified through our approach. It is also possible that this type of activity is more likely to be undertaken fully in-house by public bodies.

Figure 8 Number of Connected Places suppliers by domain



Source: *Frontier Economics analysis of Glass.ai data*

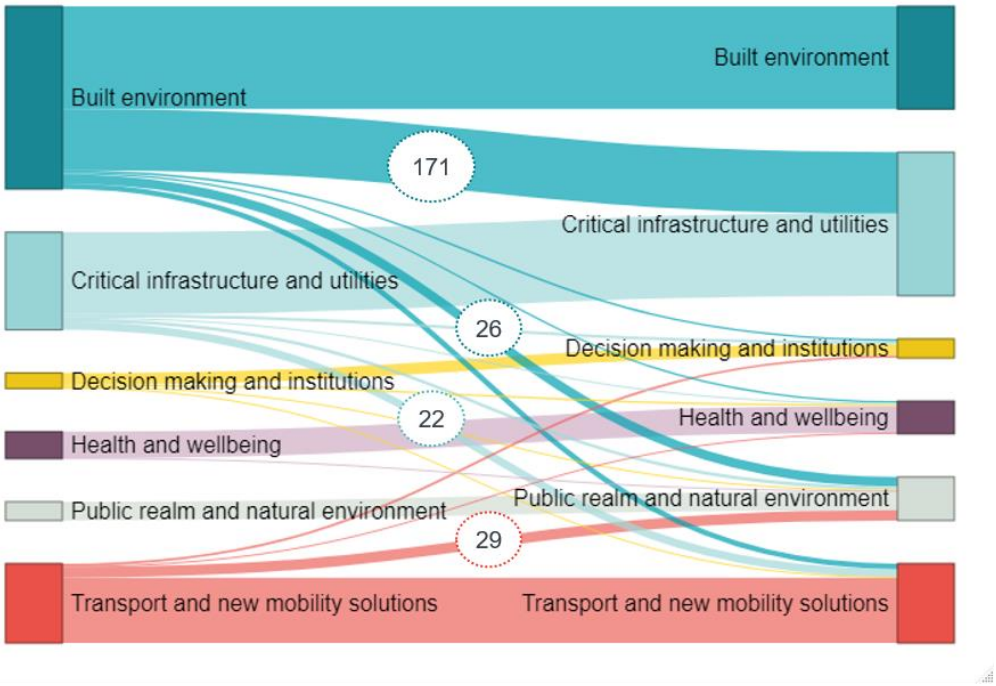
Note: *Number of companies by domain includes those that are active in more than one domain. Excludes 4% of companies that could not be assigned to any domain.*

Estimates in Figure 8 take into account the fact that companies are active in multiple domains: 36% do business in at least two domains, 13% in three domains and a further 6% in more than four. As shown in Figure 9 overleaf, most of the overlap is between “Built environment” and “Critical infrastructure and utilities” with 171 companies operating in both domains. This represents more than 44% of companies active in more than one domain. Companies doing business in both “Built environment” and “Critical infrastructure and utilities” make up 38% of all firms operating in the former domain and 34% in the latter.

A significant overlap is also found between three other pairs of domains, as shown in Figure 9 overleaf: “Transport and new mobility solutions” and “Public realm and natural environment” in the case of 29 firms (6% of those operating in more than one domain); “Built environment” and “Public realm and natural environment” in the case of 26 companies (6%); and “Transport and new mobility” and “Critical infrastructure and utilities” in the case of 22 firms (5%).[26]

[26] The full list of links between domains can be found in Annex B.

Figure 9 Links across domains



Source: *Frontier Economics analysis of Glass.ai data*

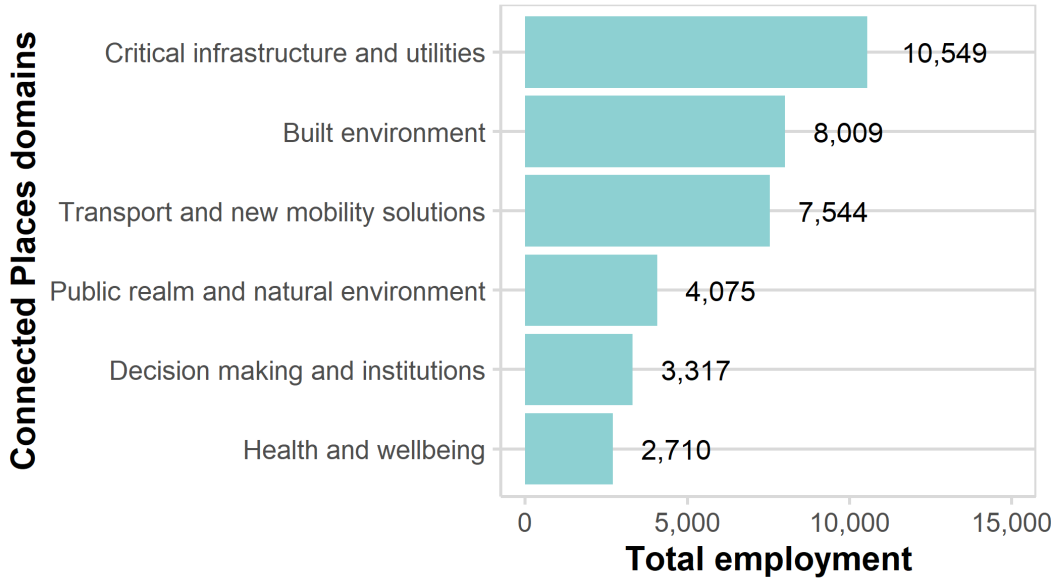
Note: *Excludes dissolved companies based on Companies House status and non-profit.*

Figure 10 overleaf provides employment estimates by domain. Given that some companies operate in more than one, job totals were split equally between the domains in which they are active.[27] Again, "Critical infrastructure and utilities", "Built environment" and "Transport and new mobility solutions" account for a large majority of Connected Places activity.

Employment in "Critical infrastructure and utilities" is larger than in any other domain, representing 29% of all Connected Places jobs. "Public realm and natural environment", "Decision making and institutions" and "Health and wellbeing" are the smallest domains in terms of total employment. As will be mentioned later in Figure 20, the first domain is composed mainly of small firms, whereas the other two include some large companies providing connected and remote care solutions (e.g. Tunstall Healthcare),medical technology devices (e.g. Becton Dickinson and Docobo), specialised advise to public organisations to improve citizen experience (e.g. Capita), or on-demand platforms across multiple domains (e.g. Amazon, Google, Microsoft).

[27] For example, if a company has 100 employees and operates in two domains, half are allocated to one domain and half to the other.

Figure 10 Total estimated Connected Places employment by domain



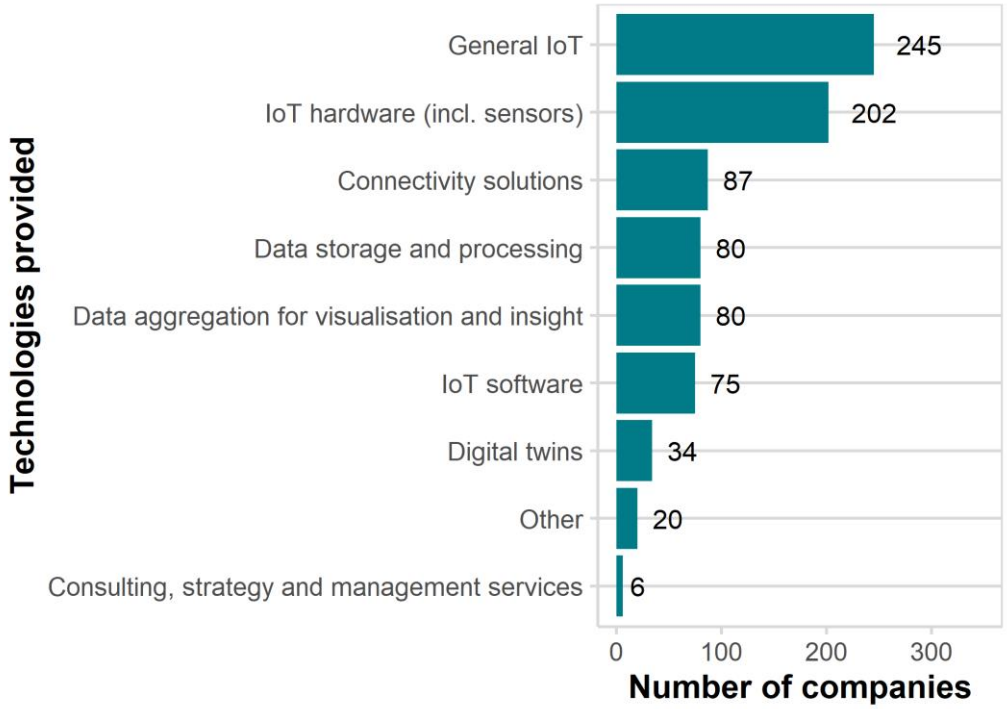
Source: Frontier Economics analysis of Glass.ai data

Note: Number of employees weighted by number of domains per company.

2.1.2 Technologies provided

Figure 11 shows the number of companies that were identified by matching technology search terms with the company's own description of its offering. The biggest matches in our dataset were with broad, general IoT terms (including for example "IoT services" and "IoT technologies"), and with IoT hardware, which includes sensors and actuators. There are fewer companies providing connectivity solutions (e.g. 5G) and data storage and management, visualisation and analytics services.

Figure 11 Number of companies by general technology categories



Source: Frontier Economics analysis of Glass.ai data

Note: Excludes 61% of companies that did not match any technology-related search terms.

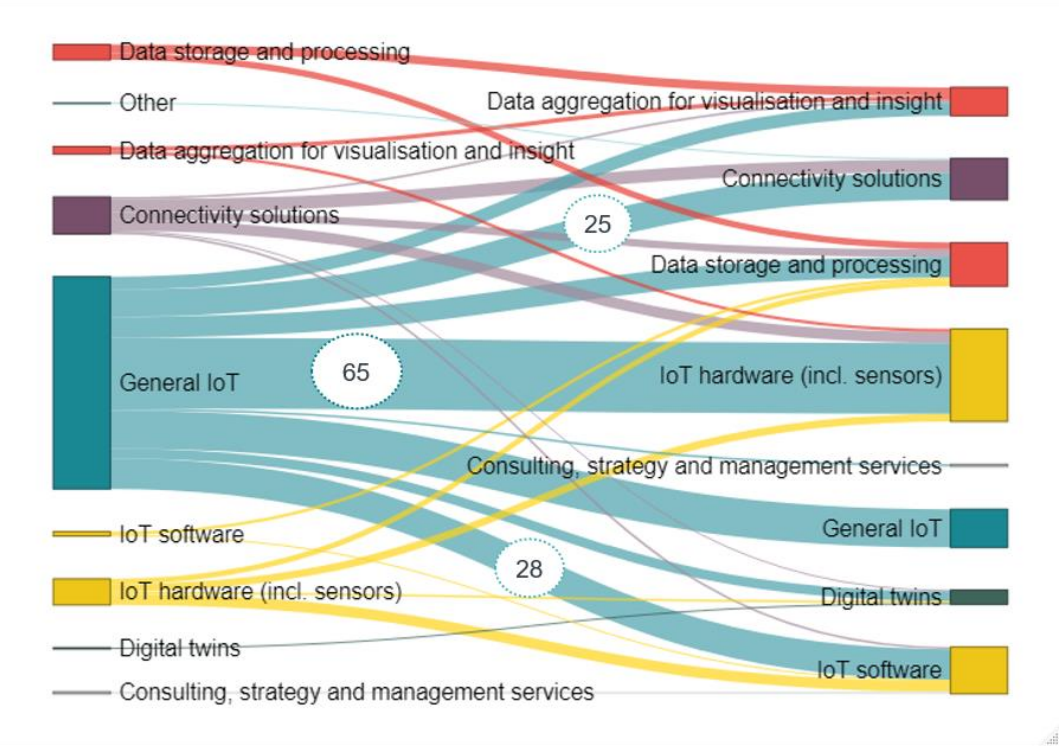
The estimates in Figure 11 include companies advertising themselves as operating in multiple categories. Of the firms that supply such information, 44% are active in more than one technology category, 27% in three categories and a further 14% in more than four. As shown in Figure 12, most of the overlap is between the general IoT umbrella term and IoT hardware and software, which includes the provision of applications, platforms and modules, among other products. This overlap accounts for 32% of companies active in more than one domain. Of the firms operating in the general IoT category, 27% provide hardware and 11% software.[28]

This finding should be interpreted with caution as the primary objective of our exercise was to identify relevant companies rather than investigate their offering in depth. It should be noted that 61% of companies in our dataset did not match any of the technology-related search terms. This is because some do not specify on their websites all the technology services they offer, focusing instead on the domains in which they operate.

However, as discussed in Section 3, our interviews confirm that large Connected Places suppliers are active across a range of technologies, often providing integrated solutions to their customers. Moreover, there are links between different technologies not only within but also between companies, with large suppliers at times relying on smaller enterprises to provide specific innovative services.

[28] The full list of links between domains can be found in Annex B.

Figure 12 Cross technology links

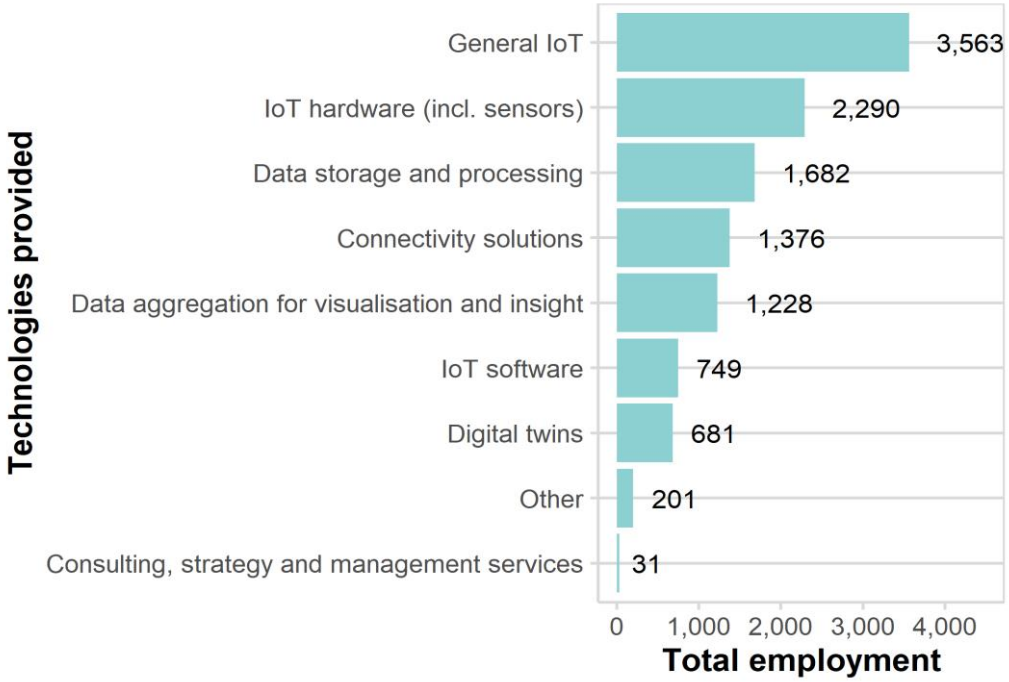


Source: Frontier Economics analysis of Glass.ai data

Note: Excludes 61% of companies that did not match any technology-related search terms.

Figure 13 shows information on total employment by general technology categories. As in the analysis by domain, employment estimates were equally distributed across the categories named by each company. More than 50% of total jobs are in companies offering general IoT services and technologies and IoT hardware, which is largely driven by very large businesses such as Bosch, Cisco, Vodafone, Ericsson, Atos and Qualcomm. Conversely, companies selling data transmission networks and consulting, strategy and management services tend to be relatively small firms established in the last five years operating locally in specific cities (e.g. Thingful or UCW Industries).

Figure 13 Total estimated employment by general technology categories



Source: *Frontier Economics analysis of Glass.ai data*

Note: *Excludes 61% of companies that did not match any technology-related search terms.*

Examples of technology solutions provided by Connected Places companies[29]

General IoT providers include, for example:

- **Freevolt (Drayson Technologies)** provides power-harvesting solutions that capture and recycle radio frequency (RF) energy from radio transmission networks (NFC, cellular, Wi-Fi, etc.) to power electrical devices such as smart and biometric cards, sensors and wearables for contactless transactions.
- **WaterWorksX (AquamatiX)** applies IoT to water management for the design of edge devices specific to particular water applications, such as wastewater pump stations or water-level sensing, and standard apps which bring together system and asset performance benchmarking with energy efficiency.

Data aggregation for visualisation and insight include, for example:

- **UrbanTide** provides a data insight platform for smart cities called USMART which offers three services: 1) data integration, 2) exploration of data into actionable insights using machine learning and AI, and 3) advanced visualisation capabilities.

IoT hardware providers include, for example:

- **Perpetuum** provides wireless remote condition monitoring systems through sensing technology to optimise railway operations.

[29] All descriptions were extracted from companies' descriptions of their own offering on their websites and in other publicly available sources.

- **bitsensing** designs sensor fusion[30] and AI solutions through radar technology for autonomous driving, smart traffic infrastructure, in-cabin sensing and advanced driver-assistance systems.

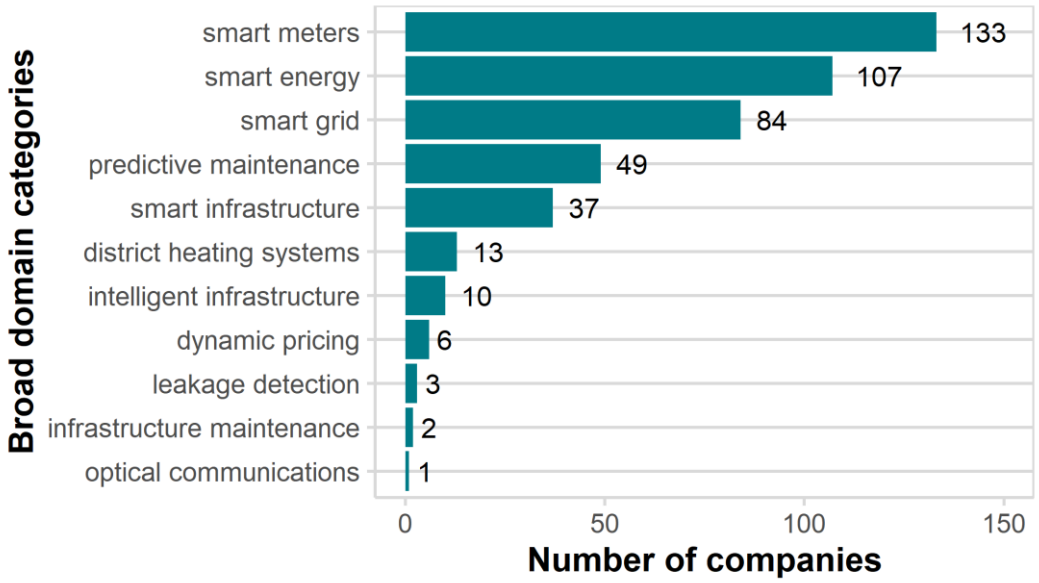
2.1.3 Services provided

We also looked at other types of terms used to identify Connected Places companies in our dataset to better understand what services are provided in each domain. As with technology terms, these results should be interpreted with caution as the primary objective of our collection exercise was to spot relevant companies rather than investigate in depth which services they offer.[31]

Critical infrastructure and utilities

As shown in Figure 14, within the "Critical infrastructure and utilities" domain the most frequently matched terms include general topics such as "smart meters" (133 companies), "smart energy" (107 companies), and "smart grid" (84 companies). This suggests that most companies in this domain are involved in providing cost-effective, sustainable and secure energy systems with a view to increasing energy efficiency and reducing consumption.

Figure 14 Critical infrastructure and utilities - Number of companies by service categories



Source: Frontier Economics analysis of Glass.ai data

[30] Sensor fusion solutions bring together inputs from multiple radars, lidars (lasers) and cameras to form a single image of the environment around a vehicle.

[31] Note: this analysis focuses on search terms related to domain activities (e.g. leakage detection) and applications (e.g. smart energy). It excludes terms related to general outcomes as they are often not domain-specific and relate to a relatively small proportion of companies in our dataset.

Examples of Critical Infrastructure and Utilities companies[32]

- **Energy Metering Technology** provides smart energy- and water-monitoring systems that aim to achieve savings in carbon and utility costs for businesses and public sector organisations (e.g. hospitals, local authorities).
- **Fulcrum** offers multi-utility infrastructure solutions, including connections, electric vehicle (EV) charging, smart metering, green heating and ventilation, and electrical maintenance to support clients in the smart energy revolution.
- **BSR Group (British Solar Renewables)** delivers smart renewable energy systems. This includes building, connecting and managing utility-scale solar generation and energy storage projects for developers and investors in the UK and internationally.

Built environment

Within "Built environment", around 90% of companies provide technologies and solutions to improve the performance of buildings by monitoring, controlling and optimising heating, ventilation, air conditioning and lighting systems.

Examples of Built environment companies[33]

- **ExcelRedstone** builds, supports and optimises the IT infrastructure, networks and connectivity of building management systems to improve building performance in terms of access control, surveillance, heating and ventilation, lighting and space optimisation.
- **McAvoy** provides construction solutions based on Building Information Modelling (BIM) to achieve optimal energy efficiency through intelligent virtual design and digital twins.
- **Trend (Trend Control Systems)** builds Energy Management Systems (BEMS) for the control and monitoring of heating, ventilation, air conditioning and other building services to minimise energy consumption and maintain consistently comfortable conditions.

Transport and mobility solutions

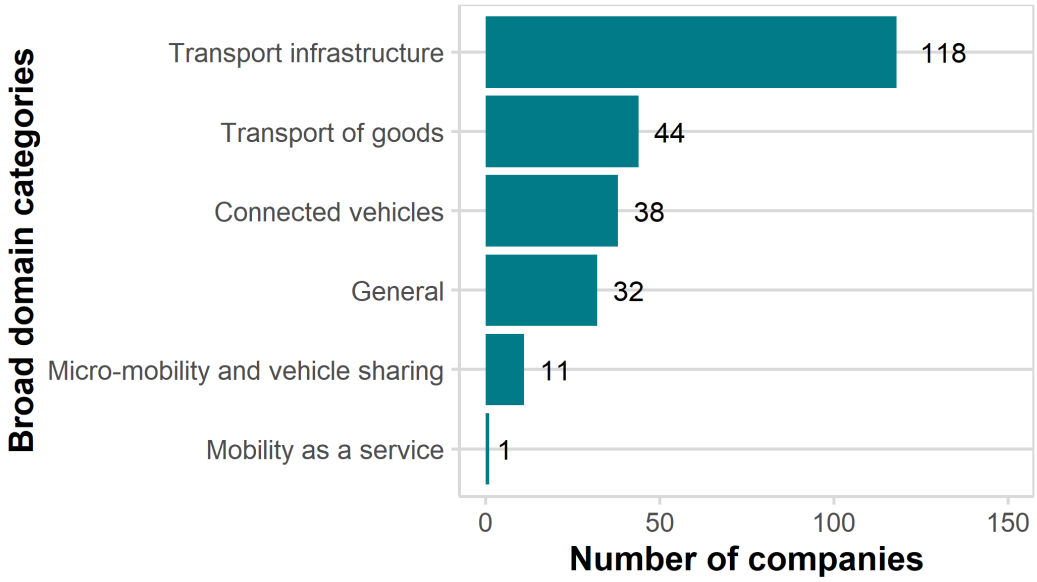
The "Transport and mobility solutions" domain appears to be more varied than "Critical infrastructure and utilities" and "Built environment". As shown in Figure 15 below, the most frequently matched terms within this domain have to do with transport infrastructure broadly defined, which includes smart parking, traffic management and smart motorways.[34] This is followed by transport of goods, which includes applications for fleet management and last-mile logistics.

[32] All descriptions were extracted from companies' descriptions of their own offering on their websites and in other publicly available sources.

[33] All descriptions were extracted from companies' descriptions of their own offering on their websites and in other publicly available sources.

[34] "Transport infrastructure" terms include smart parking, traffic management, smart airports, smart motorways, smart parking, smart roads, traffic monitoring and electric vehicle charging. "Transport of goods" terms include last-mile logistics and fleet management. "Micromobility and sharing" terms include bike and scooter sharing.

Figure 15 Transport and mobility solutions - Number of companies by service categories



Source: Frontier Economics analysis of Glass.ai data

Examples of Transport and mobility companies[35]

- **BBV - Balfour Beatty Vinci** is a civil engineering company that provides building-modelling technology for critical rail, transport and other engineering and construction projects.
- **nShift** is a provider of end-to-end cloud platforms for e-commerce, retail, manufacturing and third-party logistics shippers to automate and optimise the delivery and returns management process.
- **Dynniq** offers integrated mobility, parking and energy solutions for complex traffic management systems, intelligent transport and smart mobility systems, public lighting along national roads, remote management and maintenance of tunnels, bridges and other infrastructure.
- **Ofo UK** is a dock-less bike-sharing company operating in London, Cambridge and Oxford which seeks to reduce traffic congestion and emissions.

Health and wellbeing

More than 90% of companies in the "Health and wellbeing" domain matched the search term "telehealth", which indicates the remote provision of health and social care and related services (e.g. drugs prescription) and the use of digital tools to improve the monitoring of people in care homes, assisted living settings, etc.

[35] All descriptions were extracted from companies' descriptions of their own offering on their websites and in other publicly available sources.

Examples of Health and wellbeing companies[36]

- **Tynetec** specialises in the design and manufacture of innovative telecare and technology-enabled care solutions for independent living which are supplied mainly to local authorities and housing associations across the UK.
- **Tunstall Healthcare** is a technology company specialised in digital health and care services to enable independent living. It uses connected healthcare solutions and alarm systems to support those requiring care and health interventions both in hospital and at home.
- **HealthHero** is a digital health start-up that provides out-of-hospital primary care services and clinical support through diverse digital and telemedicine tools. Its services span GP consultations, mental health services delivered through video chat, prescription services and access to musculoskeletal specialists.

Public realm and natural environment

In the "Public realm and natural environment" domain, the most frequently matched terms are those ones related to use of technology for both environmental monitoring and emergency response (e.g. "facial recognition", "smart cctv"). This suggests that most of the activity in this domain involves security (threat and risk detection) and crowd management, along with air pollution and quality monitoring.

Examples of Public realm and natural environment companies[37]

- **Eocortex** manufactures smart camaras and video management software for surveillance systems, which includes suspect search, COVID-19 compliance, 3D people counting, face recognition, license plate recognition, tracking and crowd monitoring.
- **Cawamo** combines cloud and edge computing to transform any surveillance equipment into a smart alert system that provides real-time video analytics for threat detections and crowd management.
- **D-Tech Systems** provides environmental monitoring (sensors and transmitters), control equipment, calibration, maintenance services and data analytics for museums and art galleries.

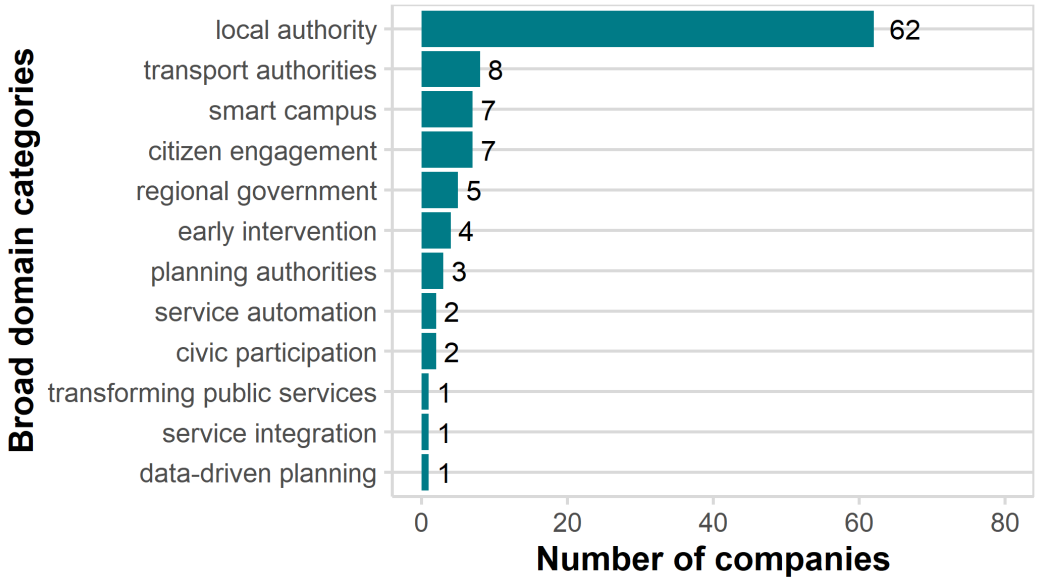
Decision making and institutions

Finally, within the "Decision making and institutions" domain we have mainly identified companies that provide a wide range of services to local governments and other public authorities. These services include data aggregation for visualisation and insights, citizen engagement platforms and civil engineering consultancy services for infrastructure projects.

[36] All descriptions were extracted from companies' descriptions of their own offering on their websites and in other publicly available sources.

[37] All descriptions were extracted from companies' descriptions of their own offering on their websites and in other publicly available sources.

Figure 16 Decision making and institutions - Number of companies by service categories



Source: Frontier Economics analysis of Glass.ai data

Examples of Decision making and institutions companies[38]

- **Cambridge Intelligence** builds data visualisation tools for a range of operations, from law enforcement to cybersecurity and fraud detection, for decision making and implementation of solutions.
- **Mott MacDonald** is a development, engineering and management consultancy active in multiple domains with particular experience in construction, communications, defence, education, environment, health, industry, transport, urban development, water and wastewater.
- **Novoville** is a modular citizen engagement platform that facilitates communication between local governments and citizens, allowing people to access a wide range of council services through mobile and web apps and chatbot interfaces.

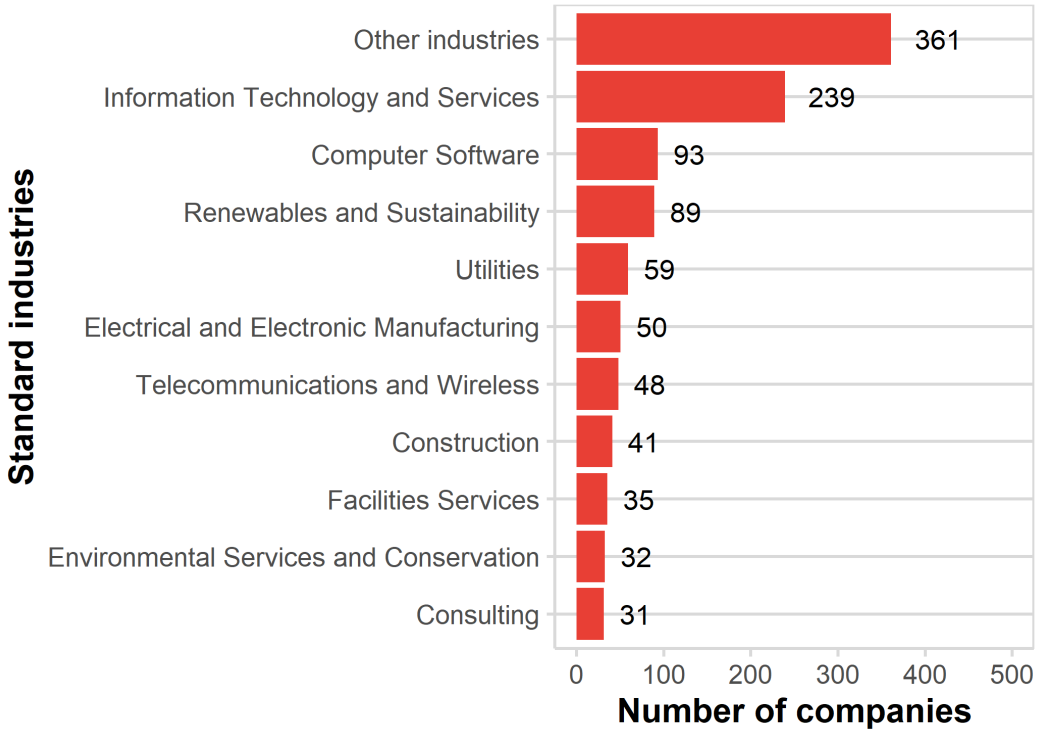
2.1.4 Market size by industry

Figure 17 shows the top 10 industry categories in our dataset, based on Glass.ai's bespoke classification system. These 10 account for 67% of the businesses captured in our dataset, with the remaining 33% (361 firms overall) operating across a wide range of other industries.[39] This highlights how difficult it would be to identify Connected Places companies based on traditional classifications – hence the need for alternative approaches like the one taken in this study. The most common industries include "Information Technology and Services", "Computer Software" and "Renewables and Sustainability". Similar results are obtained when we look at the number of employees by sector, reported in Annex B.

[38] All descriptions were extracted from companies' descriptions of their own offering on their websites and in other publicly available sources.

[39] For example, automotive; transportation, trucking and railroad; hospitals and medical practices; security and investigations; oil and energy, architecture and planning, civil engineering, among others.

Figure 17 Number of companies by standard industries



Source: Frontier Economics analysis of Glass.ai data

Note: Standard industries categorised according to Glass.ai classification.

This breakdown also shows that, although activity in the Connected Places market includes, by definition, digital and digitally enabled goods and services, not all Connected Places suppliers are part of the digital sector as defined in DCMS's economic estimates. Companies with core activities outside the DCMS sector definition make up around 58% of the total and account for around 66% of Connected Places jobs.[40] This is a common feature of digital ecosystems, where a majority of workers (such as software developers, machine-learning engineers, data scientists) are employed outside the digital sector.[41]

2.2 Composition of the market

Market composition by firm size

In line with the typical definitions used by statistical agencies, we classified Connected Places companies by size based on the number of employees. [42] Companies are categorised as micro (with 10 or fewer employees), small (with 50 or fewer), medium (with 250 or fewer) or large (more than 250).

Figure 18 and Figure 19 show the distribution of companies and total employment by firm size. We can see that 87% of Connected Places suppliers are classified as

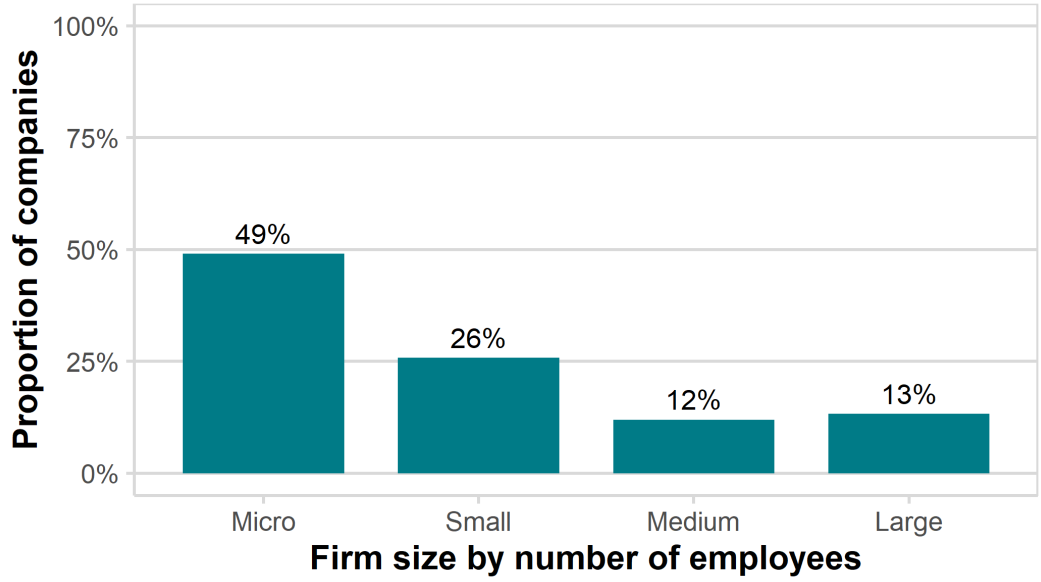
[40] This includes all companies outside the Information Technology and Services, Computer Software, Telecoms and Wireless services, Internet and Computer Network and Security, Electrical and Electronic Manufacturing industries in our dataset.

[41] Out of 1.87m digital jobs in 2017, 1.03m were in non-digital industries (e.g. retail) while 840,000 were in the digital sector. Source: Tech Nation (2019) "A Bright Tech Future".

[42] This is consistent with standard statistical definitions as used, for example, by the Office for National Statistics.

SMEs while 13% are large companies. As context, less than 1% of all UK businesses and of those in the ICT sector are large companies, so this group is over-represented in the Connected Places market.[43]

Figure 18 Estimated proportion of Connected Places suppliers by size category



Source: Frontier Economics analysis of Glass.ai data

Note: Proportions based on 854 companies for which employment information is available.

Information on the number of employees is available for 854 companies, 79% of our dataset.[44] It is likely that the other 224 firms are smaller than those for which job numbers are available. More than half of the companies with employment information missing were established in the last 10 years; they either do not have a presence on LinkedIn, or their webpage on the platform was recently created. However, our finding that large firms are over-represented in the Connected Places ecosystem is not a function of the missing data. Even if we assumed that all 224 companies were SMEs, the proportion of large companies in the dataset would be 9%, still vastly more than the average for the whole UK economy.

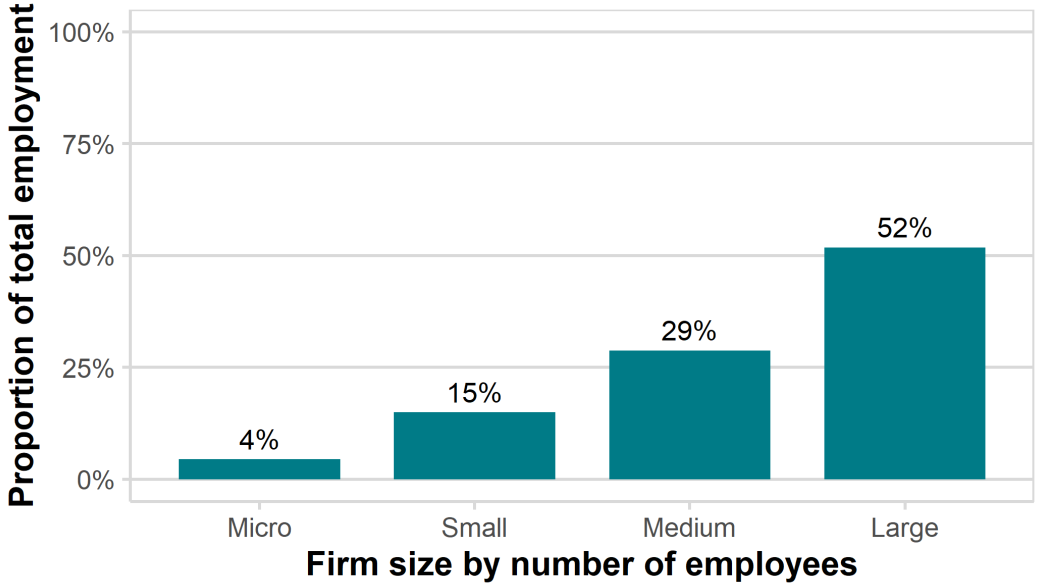
Large firms also have a particularly prominent role in Connected Places when it comes to employment. As shown in the figure below, they account for 52% Connected Places jobs, compared with only 30% across the economy.[45] Overall, our data indicates that in the Connected Places market large companies play a bigger role than they do in the UK economy as a whole and the broader digital sector. This is not to say that SMEs struggle to enter or remain in the Connected Places ecosystem due to competition from large companies. In fact, as discussed in Section 3.2, SMEs and large companies often offer different products and services; indeed, there are examples of collaboration between SMEs and large companies in delivering services to their customers.

[43] Source: ONS, Business Population Estimates 2021.

[44] These companies present the same distribution in terms of domains and technology categories as the rest of the UK Connected Places market.

[45] Source: ONS, Business Population Estimates 2021.

Figure 19 Estimated proportion of Connected Places employment by size category



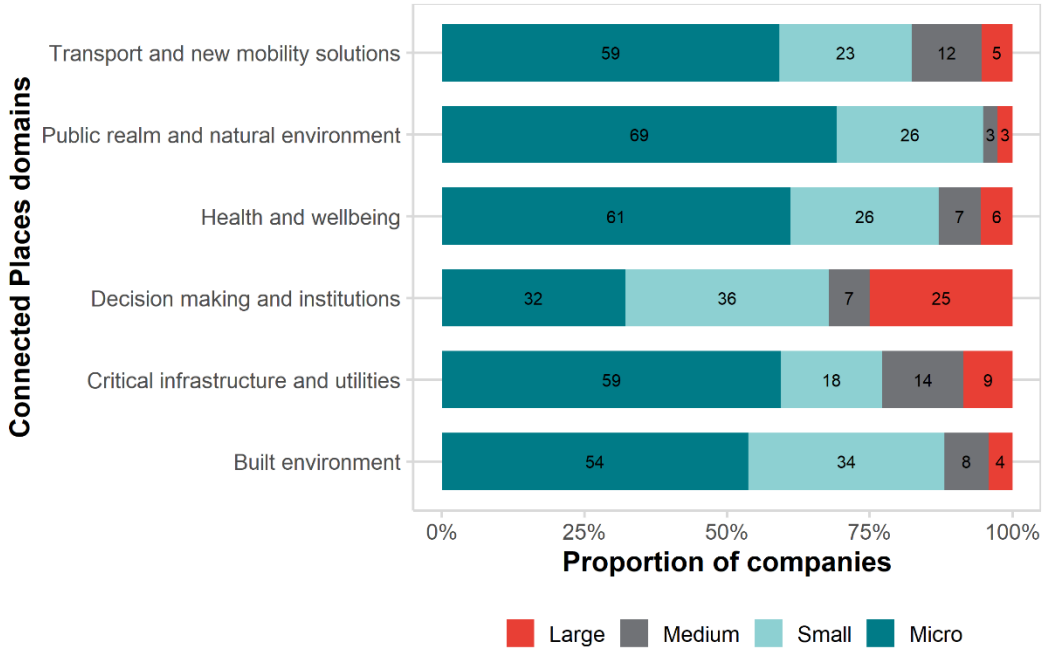
Source: Frontier Economics analysis of Glass.ai data

Note: Firm size categories constructed based on typical definition used by UK government.

When findings on the number of companies and total employment are disaggregated by domain (Figure 20 and Figure 21 overleaf), we find a higher proportion of large companies among Connected Places suppliers in "Decision making and institutions" followed by "Critical infrastructure and utilities", "Health and wellbeing" and "Transport and new mobility solutions". Examples are large engineering, construction and management companies (e.g. Mott MacDonald), energy suppliers (E.ON) and digital health and care services providers (e.g. Tunstall Healthcare, Becton Dickinson and Docobo). "Public realm and natural environment" is the domain with the largest proportion of SMEs. Large companies are more likely than SMEs to work across several domains: 63% of large companies on our dataset are active in two or more domains, compared to 35% of SMEs.

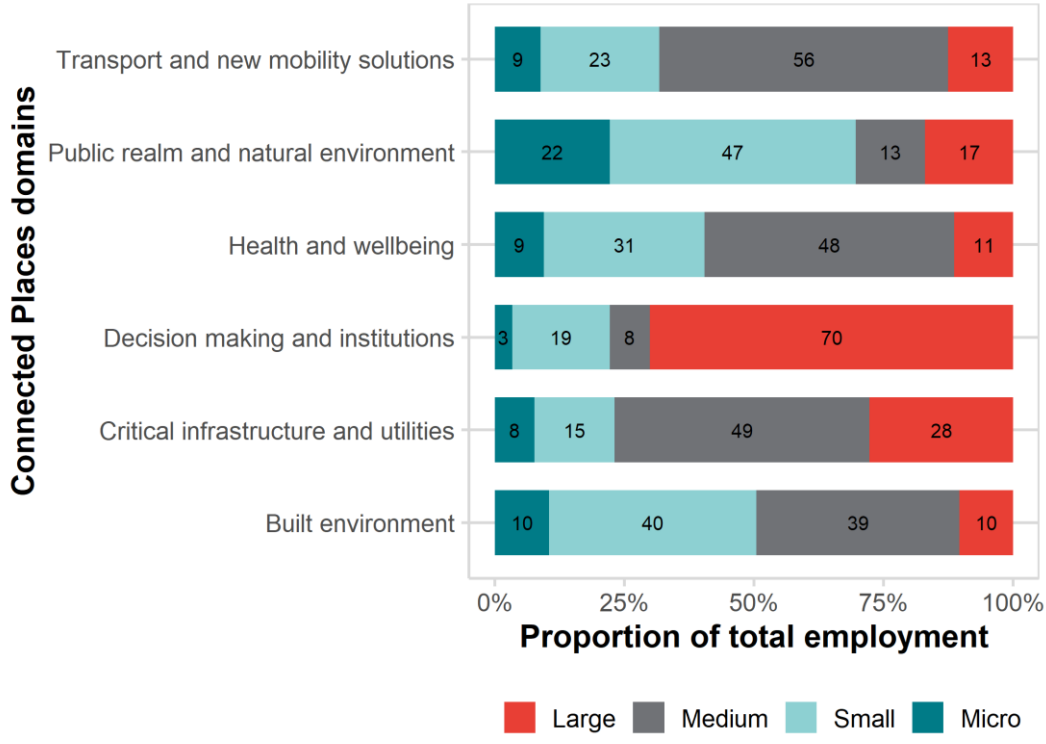
The pronounced role of large companies in the "Decision making and institutions" domain is confirmed by the finding from our interviews, discussed in Section 3, that large firms offer integrated solutions more often than SMEs.

Figure 20 Proportion of companies by domain and size



Source: Frontier Economics analysis of Glass.ai data
Note: Firm size categories based on typical definition used by UK government.

Figure 21 Proportion of estimated total employment by domain and size

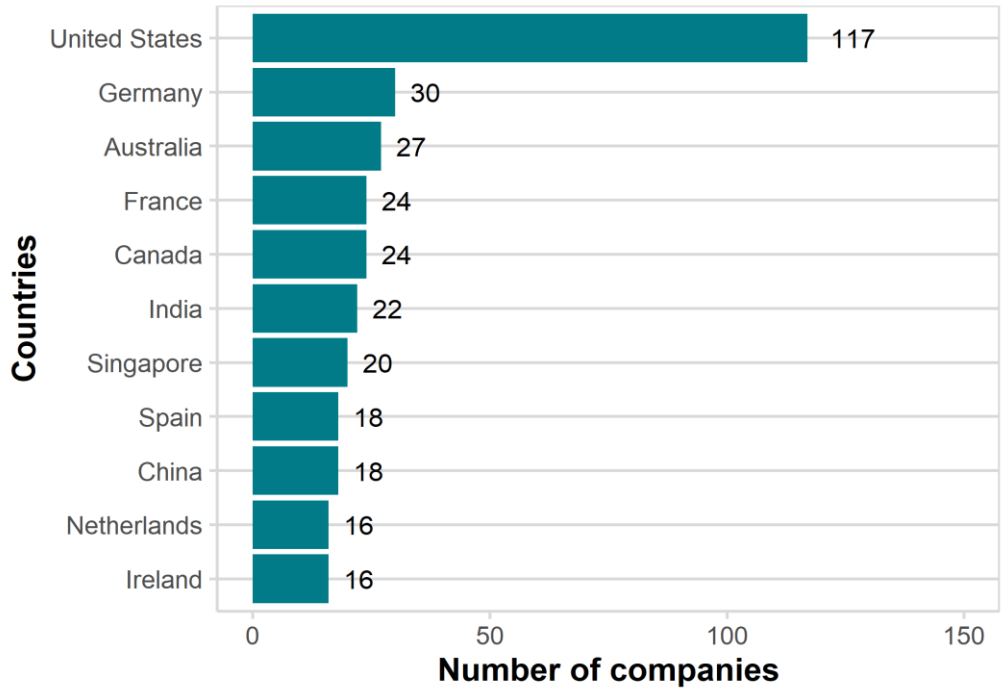


Source: Frontier Economics analysis of Glass.ai data
Note: Firm size categories based on typical definition used by UK government.

Presence in international markets

Our data shows that 19% of companies also provide services outside the UK. They do business in 73 countries.[46] The most common one is the US, as illustrated in the figure below. Germany, where 30 firms are active, comes a distant second. Eighteen companies have a presence in China, most of them headquartered in the UK; four have operations in the UK but are owned by Chinese stakeholders. The tally of 73 countries is based on information on company websites about their headquarters or offices abroad but it does not capture details of their supply chains.

Figure 22 Number of companies that are also active outside the UK, by country



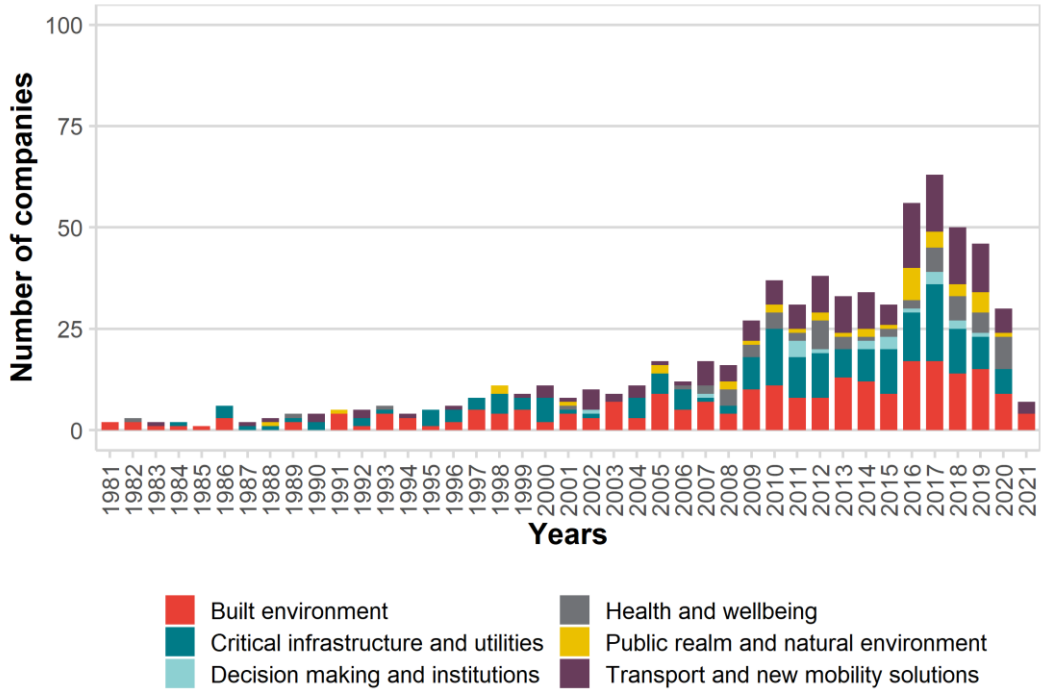
Source: Frontier Economics analysis of Glass.ai data

Market entry over time

Information on the year when active companies were set up is available for 80% of the constituents of our dataset. As shown in Figure 23, the number of newly established firms has increased considerably in the last 20 years. Consistent with the distribution of companies in the Connected Places market, the domains with the highest number of firms founded during this time were “Critical infrastructure and utilities”, “Built environment” and “Transport and new mobility solutions”.

[46] Countries outside the UK where companies are active were identified by the postcodes mentioned on their websites. Allocation of companies to the UK was based on the address of the website and where it was being managed. In most cases this should correspond to the location of the company's headquarters.

Figure 23 Number of active companies by established year



Source: Frontier Economics analysis of Glass.ai data

3 THE CHARACTERISTICS OF THE CONNECTED PLACES MARKET

3.1 Scope of our research

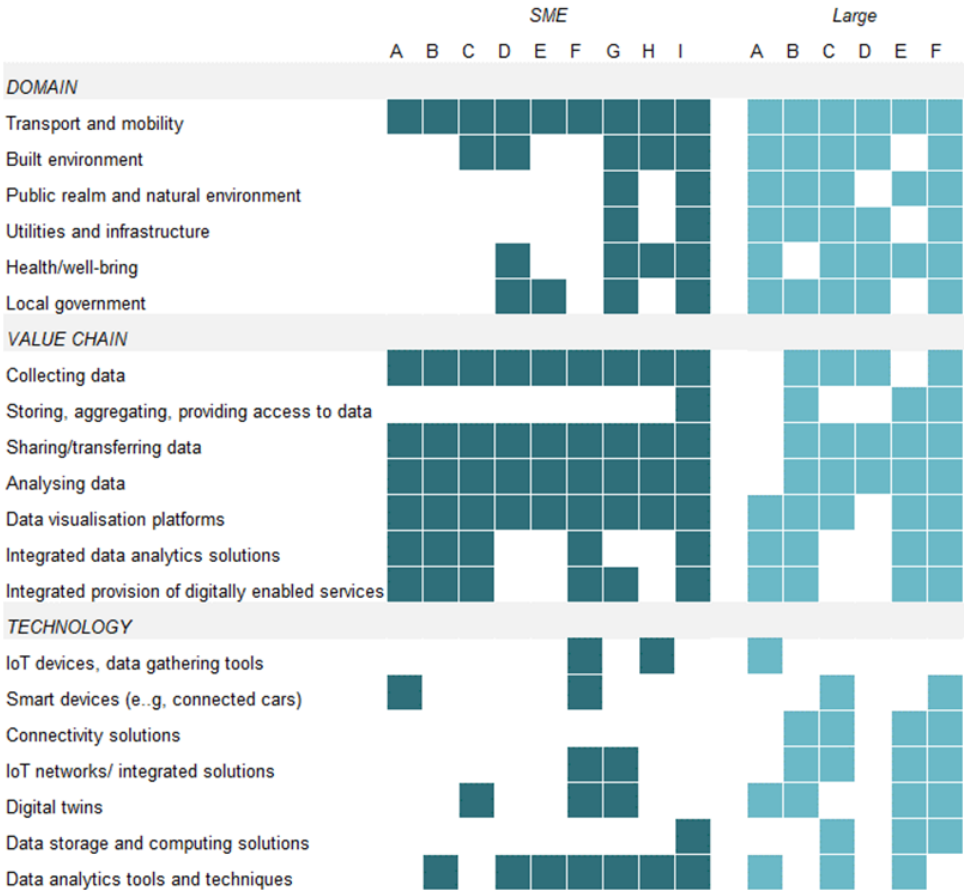
This section summarises the findings from our in-depth interviews with 20 participants active in the Connected Places market, including:

- Fifteen Connected Places suppliers, comprising six large businesses and nine SMEs;
- Three Connected Places customers (demand-side organisations); and
- Two research outfits.

As is standard practice with qualitative research of this nature, the main purpose of the interviews was to provide context for our statistical analysis on the characteristics of the Connected Places market. Our aim was to identify and drill down into the key issues so DCMS could have a more nuanced view of the market, its evolution, growth expectations and the main barriers facing its participants.

To this end, 15 of the 20 organisations we interviewed were conducted with Connected Places suppliers; six were large global businesses and nine were UK-based SMEs. We selected companies with the aim of achieving a spread of Connected Places domains and technologies and of getting a representative view of the entire value chain (discussed below). The suppliers we spoke to cover the Connected Places spectrum, as shown in the figure overleaf. However, the number of businesses able to shine a light on specific aspects of the market can be low. Therefore, our findings should be interpreted with caution. That is particularly the case for demand-side issues, since our conclusions are primarily based on interviews with Connected Places suppliers.

Figure 24 Market activity of suppliers interviewed



Source: Frontier Economics

Our coverage of the Connected Places ecosystem was relatively light on the manufacture of IoT devices and similar data-gathering tools. We were able to address this shortcoming by interviewing other organisations that procure IoT devices for integration into their systems. For example, one of the SMEs we spoke to provided specific evidence about the use of such devices in AVs. Similarly, relatively few businesses were offering storage solutions for Connected Places, but most of our interviewees were able to discuss their use of storage technologies within the context of the market.

The **three customer interviews** provided good coverage of the ecosystem from a domain and technology perspective. One organisation gave an overview of grant-funded Connected Places investments and pilot projects across several local authorities. These are seeking to address an array of issues such as improving air quality around schools, reducing road flooding and raising the quality of social housing. We also spoke to a local authority with about a decade of experience in Connected Places research, including collaborative test-bed and other grant-funded development projects. This interview furnished further evidence of the challenges being encountered in a broad range of domains, with a focus on mobility. The third demand-side conversation was with a private sector company that is investing heavily in Connected Places technologies to improve the service quality of its buildings. The domain focus was narrow, but the interviewee was able to talk in detail about the benefits of Connected Places investments.

Research methodology

The interviews were semi-structured: they were conducted as video calls using a topic guide agreed in advance with DCMS. Participants were not given an incentive or reward for their participation.

We present the evidence by highlighting key messages from the interviews accompanied by an indication whether each finding applies generally or is relevant to businesses with particular characteristics (e.g. a large firm or an SME). We also provide colour from the interviews in the form of anonymised quotes. We do not attribute evidence to an individual business. We gave the assurance of anonymity to all participants so we could elicit candid views. We are sincerely grateful to the companies we spoke to for their time and readiness to engage with us.

3.2 Characteristics of Connected Places suppliers

Our qualitative research builds on our quantitative investigations to provide further evidence on the characteristics of Connected Place suppliers in terms of:

- How long they have been operating in the Connected Places market; and
- Their place in the ecosystem (domain, technology and value chain).

3.2.1 Length of time operating in the Connected Places market

Overall, we found a marked difference between the length of time that large suppliers and SMEs have been active in the Connected Places market. Whereas many large businesses have been operating for more than 10 years, a lot of SMEs entered the market only in the last four years:

- Four of the nine **SMEs** we spoke with were established or started doing business in the Connected Places market in the **last three to four years**; and
- Three of the six **large companies** we interviewed have been active in the market for **over 10 years** (before the term ‘Connected Places’ was coined).

3.2.2 Role in the Connected Places ecosystem

The SMEs we contacted were solely focused on the Connected Places market. The majority of these businesses employed fewer than 50 full-time employees.

In contrast, the large companies we spoke to were selling into a wide range of markets. They were unable to estimate what proportion of their UK employees were doing work related to Connected Places in the UK, but they all put the number at several hundred at a minimum.

This is consistent with the findings from our quantitative research, described in section 2.2. Compared with SMEs, **large firms appear to work more extensively across the Connected Places ecosystem, particularly as far as the range of domains and the value chain are concerned**.

Overall, large companies gave the impression that their involvement with Connected Places has been intensifying year after year. They are selling more and

covering more of the ecosystem. But there was an exception to the indication that the UK's large 'generalist' Connected Places companies tend to work across multiple technologies: only one large business was active in the supply of IoT devices and other connected data-gathering tools. We were able to compensate for the shortage of insights into this niche by interviewing firms that procure IoT devices to integrate into their systems, for example AVs.

In contrast, many, **SMEs** told us they were focused on a **single technology,** such as AV technology, digital twins or geospatial tools. They tended to work across **multiple stages of the value chain** but were less likely to offer a full-stack solution (many of the SMEs were providing Application Programming Interfaces (APIs) that plugged into their clients' applications). The newer SMEs were still concentrating on proving their solution in a narrow domain (e.g. digital twins for an aspect of the built environment, or technologies for AVs. Some of the more established SMEs had diversified but only within a **single domain**, for example from shopping malls to airports within the built environment. All SMEs were relying on large businesses such as AWS or Microsoft for data storage, while one was offering data access services to its clients.

3.2.3 Competition and collaboration

Our findings again suggest there is a difference between large companies and SMEs in terms of who they compete with in the Connected Places market.

On the basis of our interviews, the two groups do not appear to be competing for the same supply contracts at present. Indeed, in some cases there is evidence of collaboration:

- The large businesses we spoke to tended to name other large companies when asked who their main competitors were.
- The SMEs we interviewed gave more varied responses. Some said they had no direct competition because their offering was unique, while others listed a mix of SME and large firms. This perhaps reflected both the present stage of the SMEs' business development and their ambition to improve on the products of established large players, for example Google Maps.

Examples of collaboration between large companies and SMEs

Large businesses told us that they rely to some extent on smaller firms to react quickly to innovation opportunities and supply them with niche Connected Places solutions. One stakeholder said they were leading several initiatives to support (and benefit from) university research, generate spin-offs and collaborate with scale-ups.

The SME supplier- and customer-side interviews turned up several examples of complementarity between SMEs and large companies. Big firms are able to bring capital to investment projects, particularly those funded by grants which stipulate the contribution of private sector capital. They also provide whole system solutions in areas such as data storage where SMEs are not active. For their part, SMEs are a source of cutting-edge thinking that can be integrated into a whole system solution. Examples of collaboration include Microsoft working with an AV developer

by providing storage benefits in kind; a local council bringing together R&D-intensive and large Connected Places suppliers through its grant-funded projects; and an SME working on kerbside management being approached by several large generalist companies to help them map out strategies in that field.[47]

Based on our SME interviews, another reason for SME-large supplier collaboration is to overcome conflicts of interest with data sharing. In a case outlined to us, a big company was unable to take the lead in a Connected Places R&D project because it would have had to handle commercially sensitive data for the market it operated in (including potentially data on its competitors). Expansion overseas is yet another reason to collaborate, we learned - in the case we were told about, the target market was the US.

Evidence of SMEs establishing themselves as specialised suppliers

Our interviews with SME suppliers revealed that some smaller players are able to secure commercial contracts on their own, without the support of a large company. We spoke to several geospatial mapping service businesses that were providing API solutions to plug into existing client systems. Another SME had secured a big development contract to supply a large organisation with an innovative Connected Places solution and was in the process of negotiating a significant follow-on contract. [48]

Large suppliers also told us that the UK commercial market appears more favourable to smaller players than other markets because many public sector tenders are divided into smaller packages than in, say, the US. [49]

Evolution of the competitive landscape

It is likely that the picture painted so far will evolve as SMEs mature and bring more cutting-edge technology to market. Many of the SMEs we spoke to were established in the last five years and so are not yet in a position to compete with more established players. In addition, our consumer interviews highlighted the fact that, to date, many SMEs have relied on grant-funded collaborative research projects to develop, test and demonstrate their innovative Connected Places technologies.

3.2.4 Market expectations

Supply-side organisations

All the supply-side companies we interviewed were bullish in their expectations of UK market growth. Five of the six large suppliers we spoke to expected the market to expand significantly over the next three to five years. One stakeholder pointed

[47] Kerbside management aim to increase the benefits of the kerbside in commercial environments by collecting and analysing information on demand (from delivery providers, taxis, other vehicle drivers) and offering bookable kerbside slots. These systems can be enforced by means of existing parking control methods.

[48] Commercially sensitive – no further detail can be provided.

[49] Note, this comment was made in the context of commercial tenders. Many public Connected Places projects are still grant-funded. In these cases a consortium is often required to include a larger company because of its ability to fulfil the private sector investment leverage condition attached to the grant.

to the UK government's commitment to digital twinning in its current 10-year expenditure pipeline as a turning point. (*"People follow the money... [they] say if the government is investing we will too."*) The COVID-19 pandemic was widely held to have helped lower market barriers. (*"In Connected Places…the technology and the aspirations and the demands from the public sector finally all came together [this year]. I don't think it's COVID-19 that's caused it, it was starting before that, but it's certainly helped to push back some of the barriers."*) And looking to the future, Connected Places technology is seen as a key tool to help tackle important problems such as climate change*. Everybody's got the challenge in terms of zero carbon and resilience. And Connected Places is going to help us achieve these challenges."*)

Several of the SMEs were only established in the last three to four years and so had few if any sales to help us assess market growth. Overall, all SMEs saw huge potential for Connected Places in the UK and globally, and their success in attracting investment to prove their concept to the market validates this view. The general consensus was that it will take another three to five years to bring digital twin and AV solutions to market. The horizon for other technologies such as geospatial tools is shorter – several products are on the market – but, again, stakeholders expected significant development over the next three to five years.

A few SME stakeholders mentioned COVID-19 in both a positive and a negative light. One commented that for their domain and technology (smart buildings), COVID-19 had created huge opportunities as firms look to adapt and increase the efficiency of their office space. But two SMEs remarked that COVID-19 had delayed implementation of Connected Places projects for smart social care and property data access.

Turning to international markets, companies pointed to the Middle East as a significant growth opportunity. A large supplier thought that Connected Places investment in the region could be particularly attractive because integrating legacy systems can be less of an issue than in Europe. The US was also highlighted by large and small suppliers alike as a key growth market. Several UK-headquartered SMEs had set up an office or partnership arrangement in the US. One SME had done so because opportunities presented by smart shopping malls in the US were greater than in the UK. Another SME felt the US was ahead of the game in the health & wellbeing/mobility markets. Specifically, they had the perception that UK companies are less aware of the benefits associated with Connected Places investment. This perception is in line with our finding in section 2.3 that the Health & Wellbeing domain in the US is much larger than in other countries.

Demand-side organisations

For our customer interviews we selected people with a lot of experience investing in and procuring Connected Places technologies, or, in one case, with good oversight and knowledge of Connected Places investment in several organisations. These stakeholders spoke of their desire to invest in Connected Places technology for several years, a recent improvement in technology availability and their use of public grants to conduct pilot projects. The overall message was that they are on the cusp of being able to realise the benefits of these trials. One stakeholder estimated it would be another 18 months before

financially viable Connected Places solutions would be widely available in their local authority (although a handful of private sector Connected Places investments were already operating following successful pilot projects).

3.3 Demand- and supply-side barriers

Our interviews with suppliers have identified eight key barriers to developing the UK Connected Places market.

The first four relate to the **supply side:**

- Interoperability issues from a supply-side technology or solutions perspective.
- Data sharing and, in particular, organisations' willingness to share their data.
- Access to technical skills by UK-based Connected Places providers.
- Access to financing and showcasing opportunities for SMEs.

The other four relate to the **demand side:**

- Client technical skills and knowledge.
- Customers' understanding of the benefits of Connected Places investment.
- Legacy infrastructure investment decisions.
- Financing and ownership structures.

3.3.1 Supply-side barriers

Interoperability

Interoperability refers to the ability to connect different Connected Places solutions to each other to form part of the same system without the need for external intervention or 'middleware'. This brings clear benefits. By raising productivity and lowering costs, system-wide access to data can increase efficiency for service providers, which should translate into an improved customer experience. It can also promote market competition and increase resilience. This reduces the risk that customers become entrenched with particular providers and ensures they have access to a wide range of solutions in the event of an incident or technological change.

The demand-side stakeholders we spoke to viewed lack of interoperability as a barrier to providing high-quality services for customers (*"We are quite nervous about there being [numerous] different smart city operating systems in the city which don't speak to each other - that would be a disaster from a user perspective…you would have to switch your apps, and from a visitor perspective it's going to be too difficult to navigate."*)

Interoperability generates benefits within and between domains. Current research to deliver a National Digital Twin for the UK is a good example of work to achieve inter-domain interoperability; a number of large suppliers referred to this project.[50]

As well as seeking to bring about data sharing between parties (which we consider separately below), several organisations we interviewed mentioned the need to

[50] National Digital Twin Programme.

coordinate to address technical, privacy and legal matters related to Connected Places. In order to do so, parties must agree on a common language or reporting standards.

Overall, suppliers differed on whether interoperability is a big barrier for the Connected Places market. Large suppliers agreed that it is, but the response from SMEs varied according to their place in the ecosystem and level of technical maturity. **This suggests that interoperability may be more of an issue for large-scale Connected Places systems (which may cut across domains).** But based on our conversations with SMEs, interoperability appears to be less of a concern for smaller-scale projects. That is because suppliers are happy to adopt client standards when developing their API or to use translators when taking in data or technologies from other sources. However, this may vary depending on whether and how these projects relate to wider Connected Places systems.

Larger Connected Places suppliers were unanimous that issues concerning **interoperability between different supplier technologies or solutions that are part of the same supply chain represent a significant barrier.** Indeed, some said it was the biggest obstacle that had to be overcome in order to develop the UK Connected Places market. (*"I don't think interoperability is given enough importance.")*

Our large supplier said interoperability was a major issue affecting the entire ecosystem; no part of the system suffered more – or less – than the rest. As the stakeholder put it, *"The problem stems from there being multiple different systems being delivered by multiple specialist technology providers (traffic light systems, building management, hospitals…)."*

Several large suppliers referred to the **lack of an ontological model**[51] that would enable distinct systems to connect. ("*It's like I've got my own Connected Places but to share it with any wider clients is a challenge because of the limitations in terms of things like ontologies and taxonomies across industry.*") We heard several times that this was a considerable issue at national level, for example in creating a national digital twin. (*"We can't do it because we don't have an ontological model that allows data to be shared consistently."*) In the mobility sector a stakeholder mentioned that National Highways was active in procuring ontological models for their business.

Within the public sector, one stakeholder highlighted the challenge posed by legacy technical investment ('technical debt'). Here it was felt that silo-based investment attitudes to systems development within national government made developing cross-cutting solutions immensely difficult and costly. ("*I think there's…a desire to break down those silos and be more interoperable, more collaborative, but the whole money aspect to be able to do this is the challenge.")*

In contrast, the **SMEs we consulted did not appear as concerned by interoperability.** This was particularly the case where the technology was in proof-of-concept phase; an SME developing AVs said it was not focusing on the issue.

[51] An ontology is a formal technique used in Connected Places solutions to represent knowledge and organise data in a standard way to enable data sharing across multiple systems. The aim for Connected Places is to develop a reference ontology that will act as an interoperability language.

SMEs providing API solutions (e.g. to link up to mobile phone retail apps or a parking enforcement tool) also said they were not worried about interoperability.

Some of the SME software engineers we spoke to were unconcerned about interoperability for their businesses simply because they saw this as a routine challenge; bringing in external data and technologies and integrating them with their systems was an every-day task. One SME developing digital twins spoke about a **new culture of interoperability and data sharing** emerging with the new generation of software engineers and innovators that will be reinforced by asset operators' desire to retain control of their assets. (*"No one wants to work in silos or be dependent on external organisations. Operators of assets want to retain control so they will demand interoperability solutions…that they can own and control. It's just a case of speaking the same language."*)

One SME did raise this as a potential future barrier and suggested that (because of the costs involved with developing and testing their solutions for interoperability) they would deliver interoperable solutions when this was included in the client brief.

In the same vein, a private demand-side business said it expected to press potential Connected Places suppliers to offer interoperable solutions, for at least some Connected Places applications, through their conditions of contract.

Data sharing

Closely related to the issue of interoperability is data sharing. All stakeholders interviewed said this was a significant barrier to market innovation and growth across the piece. There appear to be three chief issues:

- Commercial value of data: private sector companies can be (legitimately) reluctant to share data for fear or revealing commercially sensitive information or losing a source of competitive advantage. However, there may be instances where these risks can be mitigated, permitting data sharing to generate considerable benefits. Examples given by participants include car park operators sharing their data with a system that informs drivers of current parking options, or elevator companies sharing data on their lifts with companies managing the building.
- Sensitive data: public and private sector organisations can be (legitimately) wary of sharing potentially sensitive data. Again, several stakeholders felt that risks could be mitigated while releasing data that would be valuable for the development of Connected Places.
- Liability if things go wrong: public and private sector data providers are hesitant to share data if, in case of a mishap, they could be held liable for causing an accident or serious error and thus face potentially significant financial costs. Similarly, we heard examples of AV developers being reluctant to use data from third-party sources (in this case to train their AI) because their technology might be held liable for any accidents caused by inaccurate data.

Many of the people we interviewed said data ownership was a **significant problem that could be overcome within around three to five years.**

Looking at solutions, some stakeholders wanted to see **local government procurement practices** changed to ensure that city data was city property. (*"I've advised lots of councils that whenever they're doing a Connected Places procurement to insist that any data generated in the city belongs to them."*) One stakeholder pointed to the success of electric scooter trials in the UK; the Department for Transport's stipulation that operating licences could be granted only if operators agreed to verify and share their data was resulting in data sharing and improved service quality.

Another large supplier said the solution lay in developing **globally agreed data-sharing platforms** with the help of industry bodies. (*"It's now a question of getting some of the big industry bodies on board so they say this is the way we should do data sharing and this should have a knock-on effect with the supply chain."*) An SME stakeholder opposed this view saying it **would lead to greater fragmentation.** (*"OEMs (Original Equipment Manufacturers) are saying 'Oh well, I will make a universal platform to load all of the other data from the OEMs instead of me making my data available to everyone'. That's just going to fragment it even more because you can't really get the data from the other OEMs."*) Instead they proposed focusing on an API and open data-led solutions.

Access to skills

Large companies widely viewed a **lack of data science skills** in the UK (including cybersecurity knowledge) as hampering development of the Connected Places market.

The main problem appears to be on the client side, as global cross-sector competition for these skills is **pricing the public sector out of the market.** (*"With the market being so buoyant, people are going to the people who pay the most, which typically isn't government organisations."*) We address this topic in section 3.3.2 below.

On the supply side, a large company spoke unprompted about its own difficulties recruiting people with data science skills in the UK (*"We can't get enough data scientists. We're also competing against other industries, aviation, advanced manufacturing, biosciences."*). This supplier was careful to state that the problem lay in a shortage of people with **mid-level analytical skills** rather than expert-level skills. This view was echoed (also unprompted) by another large supplier, who acknowledged the work by DCMS on skills and training but said it would take several years to bear fruit.

Another SME said it had no problem hiring people with high-level software skills because it was able to afford them and had moved to London so it could recruit from the finance sector. But this firm was concerned about the **lack of hardware skills** in the UK. (*"It turns out very few people in the UK seem to know how to build a computer."*)

Access to finance and showcasing opportunities

One SME, which is developing an innovative geospatial tool, highlighted the challenges of raising growth finance and getting opportunities to showcase their innovations to potential investors and customers. This was a one-off comment.

Several other SMEs had secured investor funding to prove their concept and did not mention access to finance as an issue.

In the public sector, we were told of several examples of significant grant-funded test-bed projects and trials, but the general message was that commercially viable Connected Places solutions on a large scale are a number of years off in the UK. One reason for this cited by a demand-side stakeholder was the sheer size of investment needed for retrofitting when executing Connected Places projects and the slow return from this investment. They suggested that highlighting the environmental benefits of Connected Places could pull in the required institutional investment. (*"There's now quite a lot of institutional investors with bags of money that need to have…green investment attached to them, so there's some capital chasing green projects at the moment."*)

3.3.2 Demand-side barriers

Client technical skills and knowledge

The large supply-side players we interviewed highlighted **informational barriers** as another key factor restricting Connected Places investment. Within this we can differentiate between:

- The technical knowledge required by demand-side parties for the purposes of **commissioning** Connected Places solutions; and
- Understanding the benefits of Connected Places investment to justify investment to **shareholders** and the **wider public**.

From a **technical project design** perspective, several suppliers noted that a lack of education and knowledge of the big picture can hold back investment. (*"I think there's still a long way to go in terms of education [on the benefits of Connected Places investment]."*) It can also lead to poorly designed or over-specified commissions - asking for fully integrated solutions where targeted products may provide better value for money. One stakeholder commented that it can be tough for public sector organisations to offer competitive wages when trying to attract staff with digital skills.

Another felt that *"there's not enough good guidance out there for a client on procurement in terms of security and wider connectivity"*. We heard a similar story from an SME that had requested cybersecurity guidance from a government department to help specify a supply contract and was told there were no standards or relevant guidance.

Yet another stakeholder said bluntly that central government departments may not have people who understand the technical issues raised by Connected Places investment. It was felt that procuring agencies may be too reliant on supplier recommendations for direction and unable to make the call on the level of investment required.

One **demand-side** stakeholder with significant commissioning experience was very clear about the public sector's lack of technical skills: *"I've seen several projects fail miserably because we've just set the wrong brief, asked the wrong questions…"*.

Understanding and demonstrating the benefits of Connected Places investment

Our interviews suggest that more needs to be done so that managers taking the lead in Connected Places procurement in the private and public sectors can:

- Better understand the potential private and social benefits; and
- Incorporate these benefits into a comprehensive business investment case.

In the private sector context, one supplier said: "*It's down to the maturity of the organisation, recognising what's being developed and not saying after that I wish I could have monitored and understood all those people movements, waste tracking or whatever.*"

We spoke with a large UK business that had recently started investing in Connected Places technologies and saw the provision of Connected Places solutions as potentially giving it an edge over its rivals.

For public sector decision making, one large supplier said there was a need to better articulate the wider social benefits of Connected Places when making the case for a local investment. They suggested that the solution lay in 'story-telling the benefits': *"If you've got to stand up in a public forum and tell people to choose between connecting bins or keeping a library open… you're never going to win unless you can have the council change the way they share that message, which is 'by doing this we'll free up other resources or we'll enable other services'."*

Our interviews suggest that some local authorities are adopting an outcomes-based approach to their Connected Places investment to gain buy-in from residents. In one case this was achieved by extensive engagement with residents to ensure the investment strategy fitted in with their inclusion agenda.

It was clear from these demand-side interviews that the extensive and significant grants (many of which appear to have been EU-funded) to innovate, deploy and test Connected Places technologies are enabling local authorities to gather first-hand evidence of the benefits they produce.[52]

A related issue to benefit-led demand is political prioritisation. An SME developing solutions for social care felt Connected Places was being promoted as a way of tackling climate change at the expense of other issues such as inequality and access to public services.

Legacy investment decisions

One large supplier emphasised the drag effect on demand that is being caused by customers' **technical debt,** or legacy investment, particularly in the public sector. As a result, *"they don't necessarily have the scope to do some of the more valuable [projects], or even if they do, [they cannot] integrate it back into what they've got"*. An SME said the Connected Places market may struggle to grow in the UK because of the age of some of its infrastructure and suggested looking to other countries for solutions.

[52] For example, the South London partnership and its work with IoT technologies and the London Borough of Greenwich through its participation in the European Union-funded Sharing Cities project.

Similarly, according to a demand-side stakeholder, the barriers created by legacy siloed investments meant some Connected Places projects required "massive retrofit investments". (*"We've ended up with lots of very siloed systems. None of it talks to each other very well. It's an absolute nightmare to fix now…lots of the ambition we have is held back by those types of systems."*)

At the contractual rather than the asset level, we can also consider **legacy data ownership decisions** as another form of technical debt. In the past, local authorities did not insist on owning the data generated through their contracts. One demand-side stakeholder said it was considering negotiating to buy back the right to access data captured from one of its suppliers because it now realised the value of owning its Connected Places data (in this case to provide information on traffic light repairs).

Financing and ownership structures

One large supply-side stakeholder noted that, for built environment projects, the effectiveness of Connected Places investment can be highly sensitive to the way the project is being financed and delivered.

The owner-operator of a building has a greater incentive to consider the benefits of Connected Places solutions than a landlord or a large company whose construction arm does not work closely with the division that will be operating the building. ("*A lot of the value and the benefit you put into a Connected Places doesn't come so much to the people delivering the thing, it comes to the people running it…There's definitely a disconnect between delivering and running a physical asset.")*

3.4 Cybersecurity

Supply- and demand-side barriers may have implications for the security of Connected Places. For example, additional interoperability may be useful for the development of the market, but connecting more devices and systems to each other may create vulnerabilities. Moreover, if customers in this market lack the requisite technical skills – which our evidence suggests may be the case for some local and central government organisations – the upshot may be that cybersecurity does not receive the attention it deserves.

At the same time, views of cyber security risks and the ability of suppliers and customers to manage them may impact the future development of the market. For example, the reluctance of some organisations to share sensitive data may in part be due to concerns as to how secure it will be.

We devoted part of our interviews to exploring cybersecurity as it affects Connected Places. Our questions focused on understanding:

- Cybersecurity as a market differentiator;
- How knowledgeable and informed clients are about cybersecurity;
- Which aspects of the Connected Places ecosystem are most at risk and whether clients have invested appropriately to mitigate the risk; and

- Data storage practices.

3.4.1 Cybersecurity as a market differentiator

All the large Connected Places suppliers we interviewed said they use their **cybersecurity expertise to set themselves apart** from competitors. ("W*e're market leaders on this, so yes we do.*")

In contrast, the overarching message from the nine SMEs we interviewed was much softer. This reflected their view that, although cybersecurity was important, it was in many cases **not directly relevant** (because they do not handle sensitive data) **or not yet relevant** (because their product has yet to be integrated into a system and is relatively far from market). (*"When you first get material scale, that's when cybersecurity becomes a higher risk factor, and that's when you'll start investing in that area. It's not that we haven't invested in it, it's more we've assessed where we think the main risks are."*)

Where cybersecurity was considered a differentiator (by three SMEs), it was described as a **'good add-on'** to their ability to deliver a high-quality service, and simply **one of the tendering criteria** that needed to be met. These SMEs were ISO-accredited and had Cyber Essentials certification; one cited cybersecurity as a core company principle. One SME commented that SMEs with limited money to spend on cybersecurity could, in some cases, be at a disadvantage when competing against larger suppliers.

One interview highlighted the importance of clarity over who is responsible for maintaining cybersecurity and acting in the case of a breach. For example, the development of connected digital twins that model infrastructure systems (e.g. telecoms and water networks) requires data sharing between two asset owners. In this case, both organisations would be responsible for the security of the digital twins.

3.4.2 Client cybersecurity knowledge

Our supplier interviews gave the impression that **demand for cybersecurity in the Connected Places market is still maturing**. Unlike other sectors such as finance where clients are well informed, suppliers said Connected Places customers range from those who pay scant attention to the cybersecurity of a project they are tendering (*"Sometimes our customers haven't even thought about the idea it needs to be secure."*) to those that acknowledge the problem but require significant education and support to understand where and how much to invest.

Our interviews with suppliers suggest that, at least for the built environment, **the security standards that exist are high and progressive.** The work of the Centre for Protection of National Infrastructure was described as 'fantastic'.

However, the picture appears to be different at the project level.

Many of the SMEs we spoke to were **looking to their client to set cybersecurity levels** for a project. The evidence across our interviews with all organisation types and commissioners suggests that **clients may not always be in the best position to lead on 'security by design'**. One large supplier commented that their clients

tended to lack the required balance of focus between technology and cybersecurity. (*"Some [clients]… either come for a technology platform, and then think oh wow, you know we have to secure this; or they only come to us for the security aspects, and actually what they need is this holistic view.")* A Connected Places project commissioner was of the view that most councils do not know enough about either technology or cybersecurity to procure technology. They thought this was likely to be the case across the public sector, including the NHS. We have not been able to test this view, but there appears to be a **lack of guidance at project level.** One SME voiced concern that their public sector client had been unable to provide detailed guidance on cybersecurity for a recent project.

3.4.3 Connected Places cybersecurity risks and investment behaviour

We also explored whether suppliers' clients appeared to be channelling investment to particular sections of the Connected Places value chain, and whether this was in fact where they believe the greatest cybersecurity risks lie. Large suppliers were well placed to respond to this question; SMEs, less so, often because they have a singular focus on their part of the ecosystem.

The overarching message from larger suppliers was that clients focus too much on prevention. One commented: "*We spend a lot of time educating people that it's not just 'put a firewall at the front and if that stops everything, great', because chances are it won't stop everything.*" Similarly, a large supplier was concerned at the **lack of investment in cybersecurity monitoring systems that can react in the case of a breach.**

Turning to the **value chain and technologies** and which elements were especially important to secure, suppliers were unanimous in their response. They pointed to **human error/compromise** when handling the data that exits from a Connected Places system as the critical concern for cybersecurity. Importantly, for risk managers this was also the area that would yield the quickest returns to investment.

Large suppliers were also able to comment on **client data storage habits and risks**. A few spoke about the continued use of local storage. *"Many clients still store data on local storage in equipment rooms and these are often less cyber-secure."* Here the main issue appears to be the **cost of migrating legacy data to secure alternatives, e.g. the cloud**.

Another risk is making sure various connections are all secure when **transferring data within complex systems**. One supplier was concerned at the level of complexity in some client systems where there is a need to gain oversight over several security products and technologies.

Conversely, according to larger suppliers, the **customer view of where the key risks lie** in the Connected Places value chain appears to be influenced by numerous reports **of front-end security breaches. This is resulting in over-investment in securing system end points** (*"I'd say...the risk is less about the end devices"; "We see a lot of people...putting too much security on to things where it's not needed. Things like cameras..."*)

Finally, in line with our findings on investment incentives, projects overseen by owner-operators were significantly more likely to have a cybersecurity focus than those being delivered by an organisation that would not have responsibility for operating the system or asset (see also section 3.2.6).

3.4.4 Data storage practices

Asked **where suppliers store their (and their clients') data**, the answer from large companies tended to be **'it depends, it's up to our client and the nature of their data'.** One supplier provided a few examples, including historical traffic light data (no need to secure); AV location data (response times a priority so local storage more appropriate); sovereign data (in-country storage)[53]; project data (international cloud storage to facilitate a 'follow the sun[54]' project delivery model).

Smaller suppliers tend to use the backed-up cloud storage solutions offered by Microsoft and AWS. They felt that these companies were setting the standard in terms of security and were promoting this as a selling point to clients. Local storage was used only in one instance by one SME because the volume of data being captured made cloud storage too expensive.

All the suppliers we interviewed encrypt all of the client data that they transfer and store as well as other sensitive data. One large supplier now offers end-to-end 'homomorphic encryption', which enables them to conduct data analysis without the analyst seeing the data content. Another SME supplier uses virtual private networks (VPNs) to ensure that client data stored in the cloud can be accessed only by the relevant analysts.

[53] This refers to the requirement that data remains within its jurisdiction of origin.

[54] A system that uses teams around the globe to deliver project outputs to tight deadlines so work can be carried out around the clock.

4 COMPARING CONNECTED PLACES WITH OTHER COUNTRIES AND MARKETS

4.1 The UK market compared with other countries

In this section we analyse the quantitative data collected in collaboration with Glass.ai to assess the size and composition of the UK Connected Places market compared with a set of six developed countries (US, Canada, Germany, Spain, Singapore and Sweden). These countries were selected based on the size of their economies, recent developments in their tech ecosystem and Glass.ai expertise in European and English-speaking countries.

For this analysis we exclude companies identified through "deep crawls"[55] as this search was not carried out for other countries. Employment figures in this section do not include the 1% adjustment from large companies. [56]

In summary, the Connected Places market is smaller in the UK than in the US but larger than in Germany, Spain, Canada, Sweden and Singapore. This is the case both for the number of companies and employment. The UK has a higher proportion of companies in the "Critical infrastructure and utilities" domain than the other countries. In the UK, this domain employs around 50% of all UK Connected Places jobs. However the "Transport and new mobility solutions" domain is relatively small both with respect to the overall size of the UK Connected Places market and compared with other countries. The UK also appears to be the most diverse in terms of technology offerings.

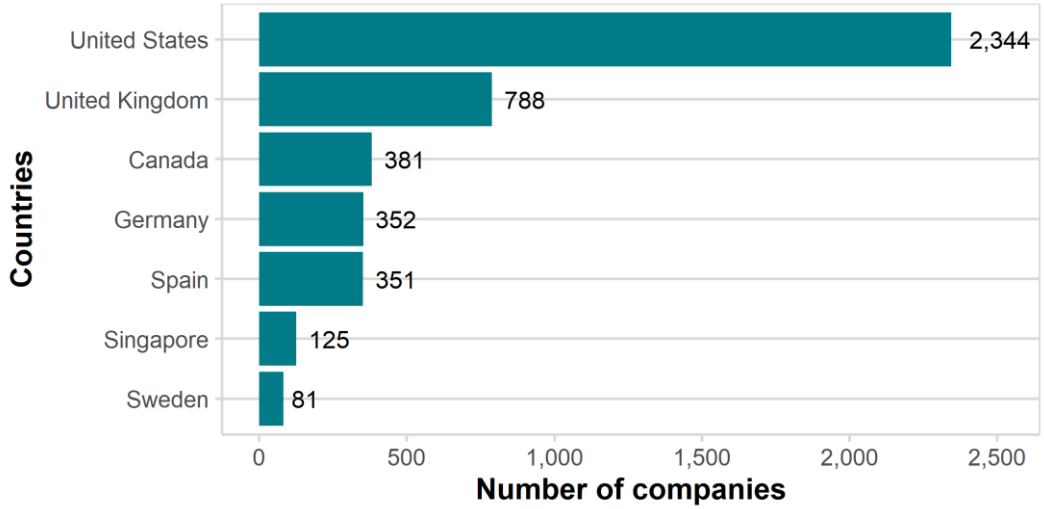
Market size by country

Overall, there are almost 4,500 companies employing more than 144,000 people operating in the Connected Places market in the seven countries considered. As shown in Figure 25, the US has the highest number of businesses, accounting for more than half of the total. The UK comes second with 18% of Connected Places firms followed by Canada, Germany and Spain, each with 8% of the sample.

[55] As mentioned in Section 1.2.2, "deep crawls" are in-depth searches on a list of 318 companies identified as likely Connected Places suppliers from existing directories and from our desk research.

[56] Estimates of the UK are not directly comparable to the other countries as we have excluded dissolved companies according to Companies House status and non-commercial operations. However, this group represents a small proportion of companies in our dataset.

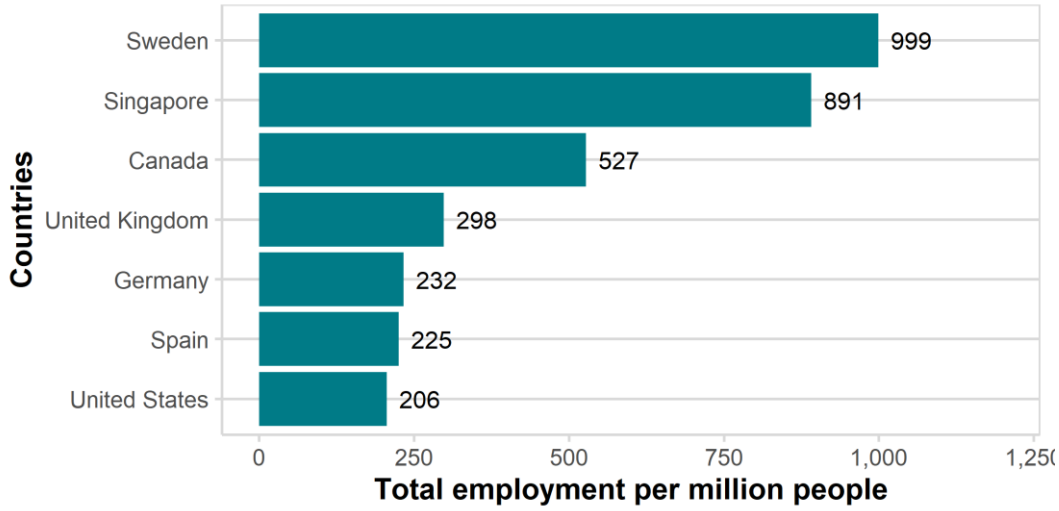
Figure 25 Number of companies by country



Source: Frontier Economics analysis of Glass.ai data

The ranking in the figure above is replicated in the total number of employees by country, reported in Annex B. However, adjusted for differences in the size of each country's economy, the number of Connected Places jobs per million people is broadly similar in the UK, Germany, Spain and the US. Smaller countries included in this study (Canada, Sweden and Singapore) have larger Connected Places activity as a proportion of overall employment.

Figure 26 Total estimated employment per million people, by country



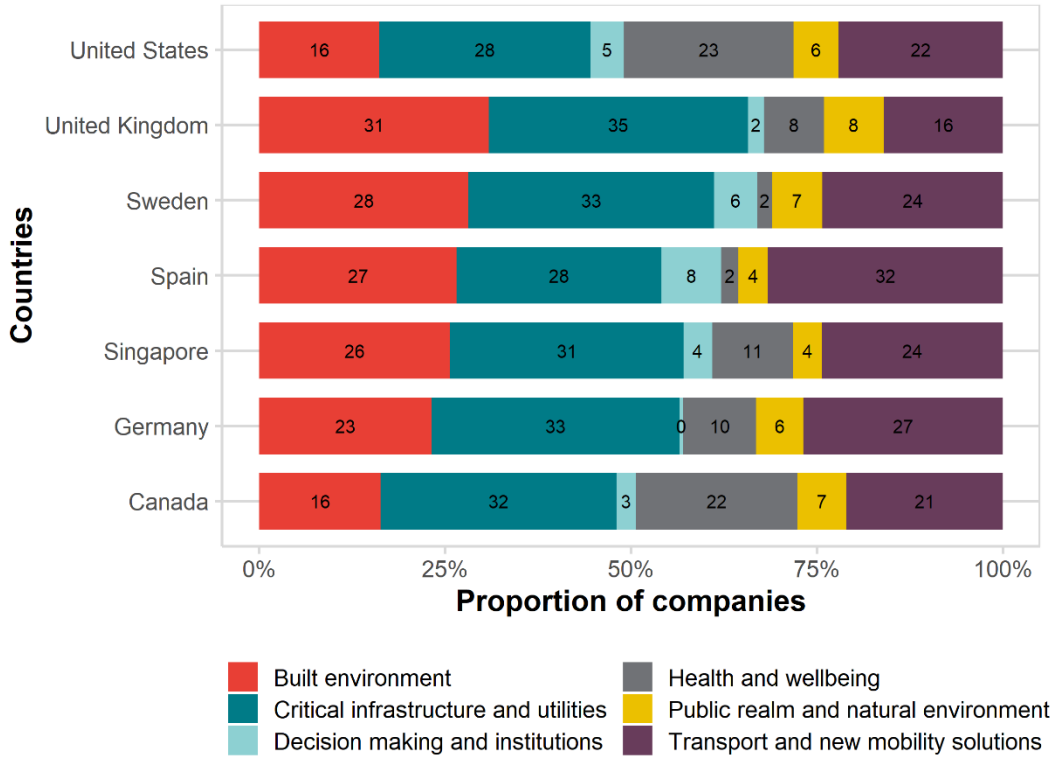
Source: Frontier Economics analysis of Glass.ai data
Note: Employment data based on LinkedIn available figures.

Market domain by country

Consistent with findings for the UK, Figure 27 shows that in most countries more than 80% of Connected Places companies are concentrated in three domains: "Critical infrastructure and utilities", "Built environment" and "Transport and new

mobility solutions". In the US and Canada, "Health and wellbeing" is also an important component of the Connected Places market, accounting for more than 20% of companies. This is probably because the private sector plays a more prominent role in the delivery of healthcare in North America than it does in UK and other countries in our sample. The "Decision making and institutions" domain remains relatively small in all countries, making up 0.5% (in Germany) to 8% (in Spain) of companies in the market. As noted earlier in this report, this domain is particularly difficult to measure as it is defined by its customer base rather than specific technologies and services.

Figure 27 Proportion of companies by domain and country

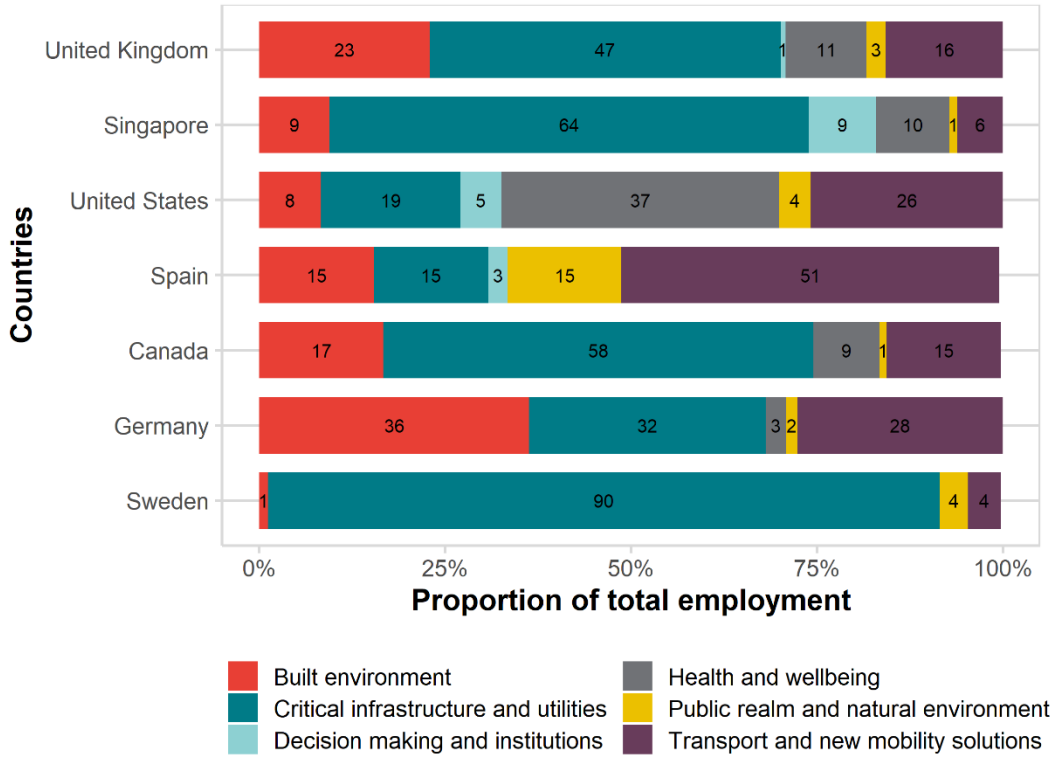


Source: Frontier Economics analysis of Glass.ai data

Figure 28 shows total employment by domain and country. In the countries considered, companies in the top three domains account for more than 80% of Connected Places jobs. In Sweden, 90% of jobs are in "Critical infrastructure and utilities", partly because of one large smart energy provider, while Spain has a higher proportion of jobs than other countries allocated to the "Public Realm and natural environment" domain.

The UK "Transport and new mobility solutions" domain is relatively small compared to the overall size of the Connected Places market: Transport and mobility companies account for 16% of UK Connected Places companies (compared to 22% in the United States, for example), and also for 16% of employment (compared to 26% in the United States, for example. Conversely, the UK's "Critical infrastructure and utilities" domain is larger than that of any other country excluding the US, both in employment and number of companies.

Figure 28 Proportion of total employment by domain and country



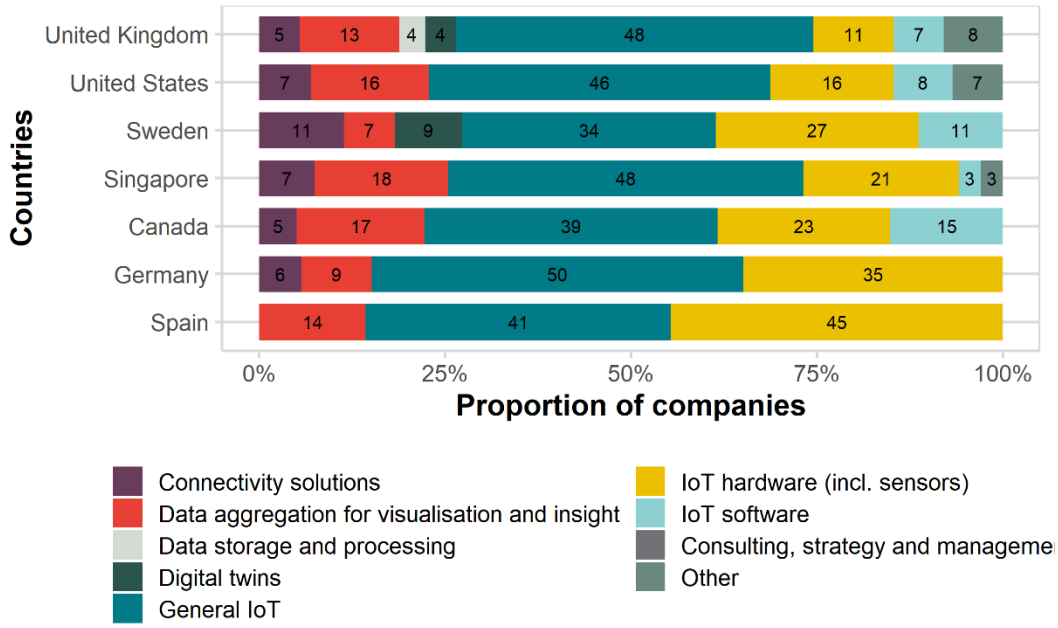
Source: *Frontier Economics analysis of Glass.ai data*

Note: *Employment data based on LinkedIn available figures. The proportion of employment in Decision making and institutions is negligible (under 0.5%) in Canada, Germany and Sweden.*

Technologies provided by country

Figure 29 shows the proportion of companies by country that were identified by matching technology terms. In line with results for the UK, we found that the most frequent technologies in our sample of countries were General IoT and IoT hardware, followed by data aggregation for visualisation and insight services. There is a smaller proportion of companies providing connectivity solutions. It is also important to mention that most of the companies offering services through the application of digital twins were identified in United Kingdom and Sweden. The UK also appears to be the most diverse country, with at least one company offering most of the technology categories.

Figure 29 Proportion of companies by general technology categories and country

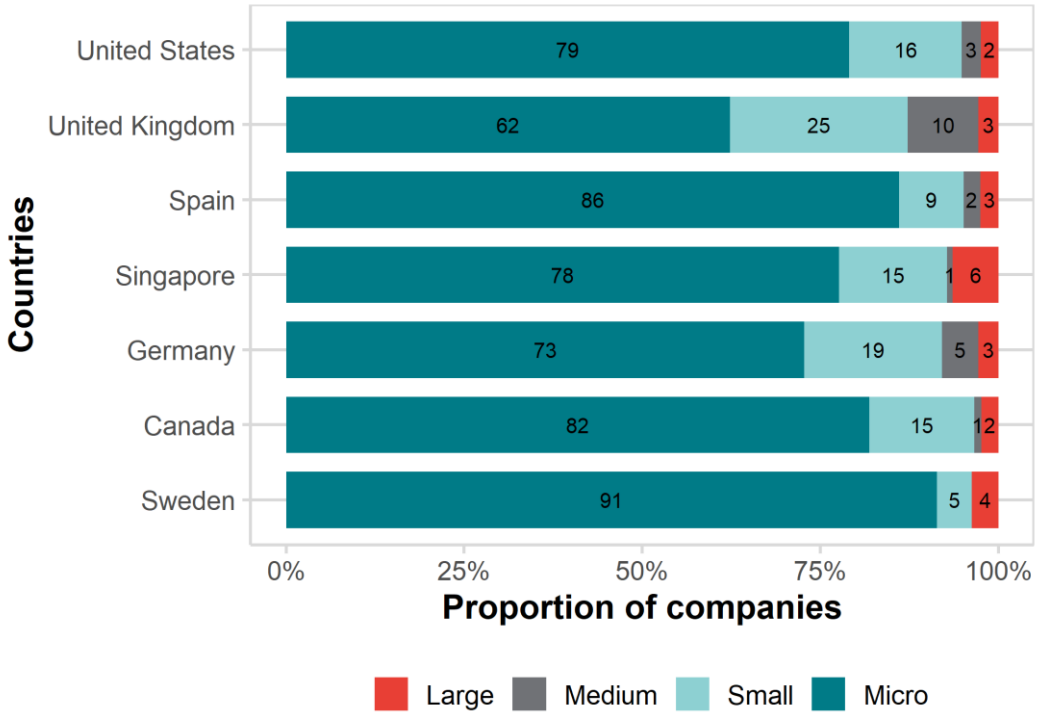


Source: Frontier Economics analysis of Glass.ai data
Note: Proportions of companies based on top 10 technology-related search matches

Market composition by country

Figure 30 presents the proportion of companies by firm size and country. As stated in Section 2, we classified Connected Places companies by size based on their number of employees. Companies are ranked as micro (with 10 or fewer employees), small (with 50 or fewer), medium (with 250 or fewer) or large (more than 250). The proportion of large companies is around 3% in every country, including the UK, with the exception of Singapore where the percentage is 6%.

Figure 30 Proportion of companies by firm size and country

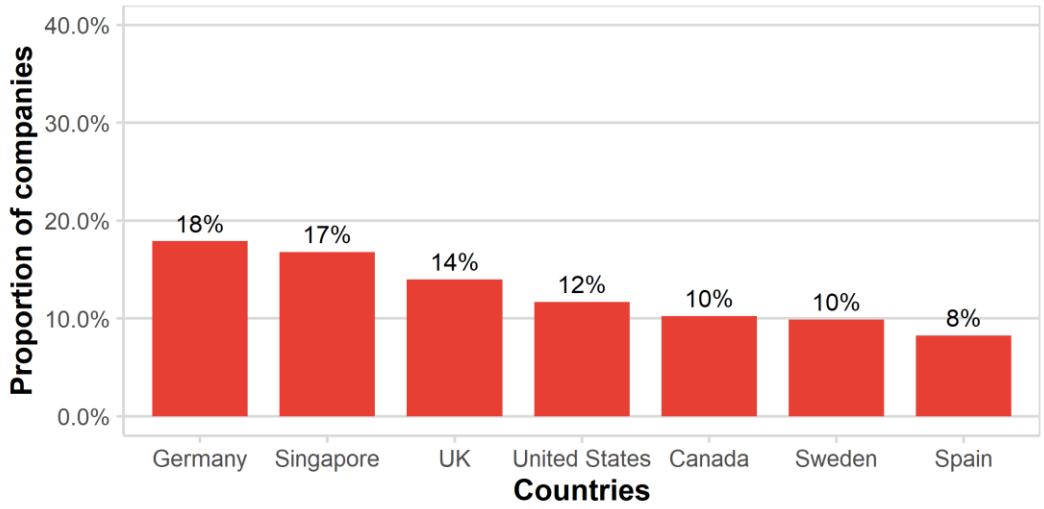


Source: Frontier Economics analysis of Glass.ai data
Note: Categories created based on employment data from LinkedIn available figures.

Companies' international presence by country

Our data shows that Germany ranks first among the seven countries with respect to the proportion of companies with commercial operations in other markets, followed closely by Singapore. The US and the UK have the widest international reach, with a presence in more than 70 countries. As mentioned in Section 2.2, the country where UK companies are most active is the US, followed by Germany. For other English-speaking countries, the US and India top the list, while companies in Spain have a greater presence in Latin America.

Figure 31 Proportion of companies with operations in international markets



Source: Frontier Economics analysis of Glass.ai data

4.2 Comparison with other digital markets

In this section we compare the size and characteristics of the Connected Places market with three other ecosystems. The purpose is to provide wider context for our findings on Connected Places. Specifically, we seek to:

- Provide a frame of reference for our findings on the size of the Connected Places ecosystem; and
- Understand to what extent the drivers of the Connected Places ecosystem as well as the barriers to its efficient functioning are unique or, conversely, common to comparator markets. Doing so can help narrow down the menu of possible policy interventions that could support Connected Places. If the obstacles to doing business are similar, policy interventions that have worked in one market could be applied elsewhere. By the same token, a better understanding of the differences between markets can help inform how Connected Places policy interventions would need to differ from interventions in other markets.

4.2.1 Comparator choice

To achieve the objectives of this comparative analysis, we needed to identify markets that are sufficiently similar to Connected Places. Specifically, we considered sectors that are:

- Emerging, i.e. markets where technological solutions and products are evolving, rather than established markets providing primarily products or services introduced many years ago;
- Digital, i.e. markets where the use of data and digital technology is a crucial component of the products and services provided;

- Complex, i.e. ecosystems that encompass many products and services that are often interlinked and/or integrated into existing markets (such as Transport, Utilities and others in the case of Connected Places).

We also needed to select markets for which sufficient evidence is available, in particular on the size of the market, that would be comparable with our data on Connected Places in terms of coverage and methodology.

Based on these criteria, we agreed with DCMS that the three comparator markets would be:

1. The UK Cybersecurity market;
2. The UK Geospatial Data market; and
3. The European (EU) consumer Internet of Things (IoT) market.

These markets have been studied in recent reports which we rely on in the following sections.[57] However, there are some gaps in the evidence base, chiefly:

- For the UK Cybersecurity market, there is detailed data on its size and composition but limited evidence on how it functions;
- Conversely, the European Commission (EC)'s inquiry into the EU consumer IoT market provides extensive evidence on its functioning but limited data on its size.

4.2.2 Size and composition

Market size

The Connected Places market is broadly as large as the UK Cybersecurity market but smaller than the Geospatial data market. Figure 32 and Figure 33 compare the three markets in terms of employment and number of firms.

Figure 32. Market size comparison, number of companies

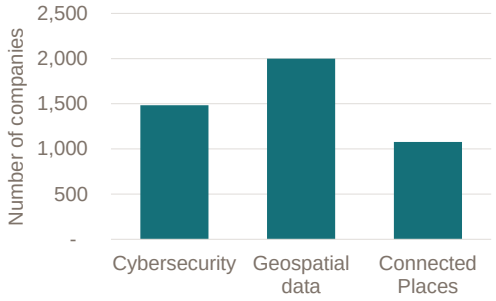
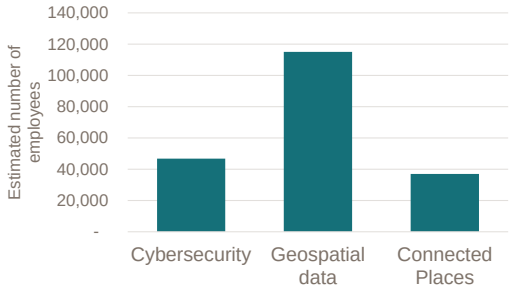


Figure 33. Market size comparison, employees



Source: *Frontier analysis of Glass.ai data on Connected Places and existing evidence on other markets*

Note: *Figures refer to most recent data available: 2021 for Cybersecurity and Connected Places, 2020 for Geospatial data*

The Geospatial Data market has the most companies of the three markets and employs many more people - 115,000, compared with 46,700 in Cybersecurity and 37,000 in Connected Places. The Geospatial data sector counts twice as many

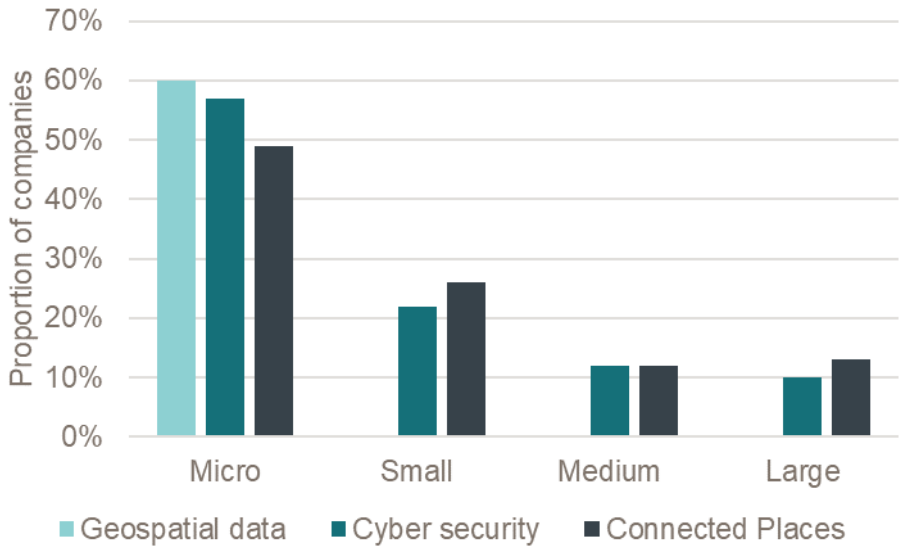
[57] Sources: Cybersecurity Sector analysis 2021; Frontier Economics (2020), "Geospatial Data Market Review", European Commission (2021), "Preliminary Report - Sector Inquiry on Consumer Internet of Things"

firms as Connected Places but nearly three times as many employees. This differential probably reflects the greater prevalence of medium-sized enterprises in the Geospatial data market.

Market composition in terms of firm size

The figure below compares the size of firms in the three comparator markets. The proportion of large companies in Cybersecurity and Connected Places is similar, at 10% and 9% respectively, and in both cases is much higher than the average across the UK economy (3%).[58] For Geospatial data, available evidence shows that 60% of firms in the market are "micro" (employing up to 10 people), and that 10% of firms have a workforce of 100 or more. For consumer IoT, no reliable data is available. However, qualitative evidence from the European Commission's sector inquiry suggests that a handful of large companies (Google, Amazon and, to a smaller extent, Apple) account for a large share of consumer IoT activities.

Figure 34 Comparison of market composition in terms of firm size



Source: *Frontier analysis of Glass.ai data on Connected Places and existing evidence on other markets*

Note: *No data available on the proportion of small, medium and large companies in the Geospatial Data market. Figures refer to most recent data available: 2021 for Cybersecurity and Connected Places, 2020 for Geospatial data*

Competitive landscape

As noted above, the EC's inquiry into the consumer IoT market points to the prominent role of a few large tech companies. According to the EC, there may be a "growing tendency towards the creation of integrated consumer IoT solutions (from the operation of cloud platforms, to the manufacture of smart speakers, smart streaming devices, and the provision of related consumer IoT services)". In contrast, the interviewees for this report did not foresee further integration as a key trend in the Connected Places ecosystem.

[58] As in Section 2, we define "large" as a company employing 250 employees or more.

5 CONCLUSIONS

The analysis set out in this report indicates that the UK Connected Places market generates a significant amount of economic activity, in line with international comparators.

The UK Connected Places market is a complex ecosystem characterised by linkages between different domains (36% of companies are active in two or more domains), technologies (44% of companies provide several categories of technology) and companies (with large firms and SMEs often collaborating to serve to end clients). Large firms account for a relatively high share of total Connected Places companies and jobs. Moreover, many small businesses often rely on large firms for data storage and processing. However, our interviews also indicate that large companies at times count on SMEs for innovative thinking on new projects.

The UK Connected Places ecosystem is somewhat smaller than other digital sectors, including the cybersecurity market. However, most participants in our study thought that a tipping point is close that will enable digital technologies and Connected Places solutions to be applied at scale. As such, they expect significant growth in the next few years. This would suggest that now is a good time to consider the role for policy interventions in the Connected Places market.

Implications for policy

We have identified the following key issues that may hinder the growth of a secure UK Connected Places ecosystem:

- **Barriers to data sharing** between suppliers, and between customer and supplier organisations. This stems from concerns on the part of data holders as well as a lack of standardisation in data and data-sharing approaches.
- **Difficulty in accessing technical skills**, particularly for public sector customers. More broadly, suppliers feel that a **lack of technical knowledge** in customer organisations and a poor understanding of cybersecurity are limiting the amount of investment in Connected Places and reducing the effectiveness of that investment. In particular, a sounder grasp of cybersecurity would allow security to be embedded as a key element in the design of a project rather than a separate requirement on supplier organisations.
- Relatedly, supplier organisations reported a **disconnect between demand-side and supply-side perceptions of where the main cybersecurity risks lie**. According to our interviews, customers are focused on the security of front-end devices and on preventing breaches. This means less attention is paid to the security of data transfer, data storage and other back-end functions, and to the monitoring of breaches.
- Limited **interoperability** between products and solutions. This is a problem of varying seriousness, so addressing it by focusing on specific domains or technologies may prove more rewarding than an ecosystem-wide approach. This issue could be explored further.

Opportunities for further research

This report provides an overview of the state of the Connected Places market and its functioning across the spectrum of domains and technologies. It also identifies questions that may warrant further exploration to inform the formulation of policy interventions and, crucially, how to target them at specific domains or technologies:

- As indicated above, there is scope for policy to support Connected Places by providing additional guidance and standards for interoperability. But this may be less appropriate for those parts of the market where new technology is still being developed (e.g. autonomous vehicles).
- It would be useful to explore through further research whether security concerns are preventing data sharing, and to what extent interventions that bolster greater confidence in the cybersecurity of Connected Places would lead to more sharing. Note, however, that there is a possible unintended consequence: interventions to expand data sharing and interoperability may carry a risk of increasing the vulnerability of Connected Places.
- Most of the SMEs we interviewed did not consider cybersecurity issues to be directly relevant to their work – at least not yet - as many were still developing new products. It could be useful to gather additional evidence on the cybersecurity practices of SMEs to understand whether they are underestimating the risks, and in particular:
  - To understand what consideration they give to cybersecurity when products are used at scale;
  - To explore awareness of risks and sensitivities related to the use of non-personal data.

Glossary

Key terms used in this report include the following:

Cloud computing. A service model for computing services based on a set of computing resources that can be accessed in a flexible, elastic, on-demand way with low management effort.[59]

Digital twin. A digital twin is a relevant, virtual representation of the state and behaviour of something physical or non-physical with a functional output in the real world. More simply put, a digital twin is a digital copy of a real-life asset, process or system.[60]

Internet of Things (IoT). IoT is an umbrella term that reflects an evolution of technology towards a proliferation of cheap devices connected to a network. It may comprise sensors that collect and transmit data, systems that make use of aggregated data, and actuators that, on the basis of this information, take action with or without direct human intervention. The term IoT is used across a spectrum of applications, from the smallest connected sensors and devices to large-scale platforms that can be deployed with physical infrastructure.[61]

Gross Value Added (GVA). GVA measures the contribution to the economy of each individual producer, industry or sector in the UK. It is used in the estimation of gross domestic product: GVA + Taxes on Products − Subsidies on Products = GDP.[62]

[59] Source: OECD (2014), "Cloud Computing: The Concept, Impacts and the Role of Government Policy".

[60] Source : techUK.

[61] Source: Royal Academy of Engineering (2018), "Internet of Things – Realising the potential of a trusted smart world".

[62] Source: DCMS.

Annex A METHODOLOGY

The Glass.ai approach

Glass.ai provides an Artificial Intelligence (AI) algorithm that reads the web using a proprietary language. The AI technology understands written language and reads millions of web pages, including organisations' websites, news reports, social media, event notices and academic and official sources. The Glass.ai engine has already mapped large parts of the UK economy based on its web profile. It regularly reads the websites of 2m+ UK businesses in every sector and part of the country.

Based on our operational definition of the Connected Places market, we used two methods to identify suppliers:

1. We use **keywords and selection rules** based on company descriptions. The Glass.ai approach allows us to identify Connected Places suppliers based on descriptions of what they do and what they offer given on their websites and in other web sources (Companies House, LinkedIn, social media, etc.). The attribution of companies to the UK or to other countries was based on the URL of their websites and where they were being managed. Keywords were translated into Spanish and German.
2. For the UK only, to ensure fuller coverage we use **"deep crawls"** - in-depth searches of a list of selected firms identified from existing Connected Places directories (UK Smart City Directory, CrunchBase, Smart Business Show exhibitors) and our desk research (D&B Hoovers).

Identifying firms through keywords

We use a list of around 200 keywords to map companies into the Connected Places market according to their description of their business. We put these keywords into six categories based on our operational definition of the Connected Places market: general ecosystem, general technology, general domain, domain-specific applications, domain-specific activities and domain-specific outcomes. A full list of search terms classified according to each category is set out below.

Figure 35 Full list of search terms

Search term	Term category	Domain (if relevant)
5g	General technology	
actuators	General technology	
advanced visualisation	General technology	Decision making and institutions
autonomous technology	General technology	
cloud integration	General technology	
cloud platform	General technology	
data analytics	General technology	
data exchange	General technology	
data integration	General technology	
data sharing	General technology	
digital twins	General technology	

Search term	Term category	Domain (if relevant)
drones	General technology	
edge computing	General technology	
edge devices	General technology	
edge sensors	General technology	
embedded chips	General technology	
embedded devices	General technology	
endpoint devices	General technology	
environmental sensors	General technology	
facial recognition	General technology	
fog computing	General technology	
information exchange	General technology	
information sharing	General technology	
integrated analytics	General technology	
internet of things (IoT)	General technology	
iot analytics	General technology	
iot application development	General technology	
iot applications	General technology	
iot devices	General technology	
iot gateways	General technology	
iot hardware	General technology	
iot management	General technology	
iot microcontroller (MCU)	General technology	
iot modules	General technology	
iot monitoring	General technology	
iot networks	General technology	
iot operations	General technology	
iot platforms	General technology	
iot product	General technology	
iot sensors	General technology	
iot services	General technology	
iot software	General technology	
iot software development	General technology	
iot solutions	General technology	
iot strategy	General technology	
iot technologies	General technology	
iot technology	General technology	
location information	General technology	
location intelligence	General technology	
low power wide area (LoRAWAN)	General technology	
low power wide area (LPWAN)	General technology	

Search term	Term category	Domain (if relevant)
mesh network	General technology	
near-field communication (NFC)	General technology	
optical networking	General technology	
radio-frequency identification (RFID)	General technology	
rfid readers	General technology	
rfid solutions	General technology	
sensor networks	General technology	
sensor technology	General technology	
smart devices	General technology	
vehicle-to-infrastructure communication (V2I)	General technology	
vehicle-to-pedestrian communications (V2P)	General technology	
vehicle-to-vehicle communication (V2V)	General technology	Transport and new mobility solutions
vehicle-to-everything communication (V2X)	General technology	
web of things	General technology	
wide area connectivity	General technology	
wireless sensors	General technology	
wireless smart utility network (Wi-SUN)	General technology	
connected places	General ecosystem	
future cities	General ecosystem	
smart cities	General ecosystem	
smart city	General ecosystem	
smart cctv	General domain	Public realm and natural environment
connected vehicles	General domain	Transport and new mobility solutions
digital assistive technology	General domain	Health and wellbeing
future aviation	General domain	Transport and new mobility solutions
geolocation	General domain	Transport and new mobility solutions
intelligent infrastructure	General domain	Critical infrastructure and utilities
intelligent transportation systems	General domain	Transport and new mobility solutions
location data	General domain	
optical communications	General domain	Critical infrastructure and utilities

Search term	Term category	Domain (if relevant)
optical transport	General domain	Transport and new mobility solutions
service automation	General domain	Decision making and institutions
smart airports	General domain	Transport and new mobility solutions
smart buildings	General domain	Built environment
smart cameras	General domain	Public realm and natural environment
smart campus	General domain	Decision making and institutions
smart energy	General domain	Critical infrastructure and utilities
smart grid	General domain	Critical infrastructure and utilities
smart infrastructure	General domain	Critical infrastructure and utilities
smart kiosk	General domain	
smart meters	General domain	Critical infrastructure and utilities
smart motorways	General domain	Transport and new mobility solutions
smart parking	General domain	Transport and new mobility solutions
smart ports	General domain	Transport and new mobility solutions
smart surveillance	General domain	Public realm and natural environment
smart transport	General domain	Transport and new mobility solutions
automated ticketing	Domain-specific applications	Transport and new mobility solutions
building energy management	Domain-specific applications	Built environment
crowd monitoring	Domain-specific applications	Public realm and natural environment
data-driven planning	Domain-specific applications	Decision making and institutions
demand planning	Domain-specific applications	Critical infrastructure and utilities
district heating systems	Domain-specific applications	Critical infrastructure and utilities
e-bike sharing	Domain-specific applications	Transport and new mobility solutions
e-scooter sharing	Domain-specific applications	Transport and new mobility solutions
future air mobility	Domain-specific applications	Transport and new mobility solutions

Search term	Term category	Domain (if relevant)
indoor positioning	Domain-specific applications	Built environment
last-mile logistics	Domain-specific applications	Transport and new mobility solutions
mobility-as-a-service (MAAS)	Domain-specific applications	Transport and new mobility solutions
predictive maintenance	Domain-specific applications	Critical infrastructure and utilities
property management system	Domain-specific applications	Built environment
rail autonomy	Domain-specific applications	Transport and new mobility solutions
remote healthcare	Domain-specific applications	Health and wellbeing
smart traffic management	Domain-specific applications	Transport and new mobility solutions
smart waste collection	Domain-specific applications	Critical infrastructure and utilities
telehealth	Domain-specific applications	Health and wellbeing
traffic monitoring	Domain-specific applications	Transport and new mobility solutions
adult social care	Domain-specific activities	Health and wellbeing
aerial mapping	Domain-specific activities	Built environment
assisted design	Domain-specific activities	Built environment
assisted living	Domain-specific activities	Health and wellbeing
assisted planning	Domain-specific activities	Decision making and institutions
building management	Domain-specific activities	Built environment
building performance	Domain-specific activities	Built environment
building retrofit	Domain-specific activities	Built environment
citizen engagement	Domain-specific activities	Decision making and institutions
civic participation	Domain-specific activities	Decision making and institutions
crowd management	Domain-specific activities	Public realm and natural environment
demand planning	Domain-specific activities	Critical infrastructure and utilities
digital mapping	Domain-specific activities	Built environment
dynamic pricing	Domain-specific activities	Critical infrastructure and utilities
early intervention	Domain-specific activities	Decision making and institutions
electric vehicle charging	Domain-specific activities	Transport and new mobility solutions

Search term	Term category	Domain (if relevant)
emergency response	Domain-specific activities	Public realm and natural environment
environmental monitoring	Domain-specific activities	Public realm and natural environment
extended care	Domain-specific activities	Health and wellbeing
facility management	Domain-specific activities	Built environment
fleet management	Domain-specific activities	Transport and new mobility solutions
health monitoring	Domain-specific activities	Health and wellbeing
homes for healthy ageing	Domain-specific activities	Health and wellbeing
independent living	Domain-specific activities	Health and wellbeing
infrastructure maintenance	Domain-specific activities	Critical infrastructure and utilities
intelligent tracking	Domain-specific activities	Transport and new mobility solutions
leakage detection	Domain-specific activities	Critical infrastructure and utilities
local authority	Domain-specific activities	Decision making and institutions
local government	Domain-specific activities	Decision making and institutions
micro-mobility	Domain-specific activities	Transport and new mobility solutions
on-demand transit	Domain-specific activities	Transport and new mobility solutions
park maintenance	Domain-specific activities	Public realm and natural environment
planning authorities	Domain-specific activities	Decision making and institutions
regional government	Domain-specific activities	Decision making and institutions
risk detection	Domain-specific activities	Public realm and natural environment
route optimisation	Domain-specific activities	Transport and new mobility solutions
route planning	Domain-specific activities	Transport and new mobility solutions
service integration	Domain-specific activities	Decision making and institutions
service targeting	Domain-specific activities	Decision making and institutions
smart tracking	Domain-specific activities	Transport and new mobility solutions
street maintenance	Domain-specific activities	Public realm and natural environment
temperature control / heating	Domain-specific activities	Built environment

Search term	Term category	Domain (if relevant)
threat detection	Domain-specific activities	Public realm and natural environment
traffic management	Domain-specific activities	Transport and new mobility solutions
transforming public services	Domain-specific activities	Decision making and institutions
transport authorities	Domain-specific activities	Decision making and institutions
ventilation	Domain-specific activities	Built environment
air pollution	General outcomes	Transport and new mobility solutions
green transport	General outcomes	Transport and new mobility solutions
healthy streets	General outcomes	Transport and new mobility solutions
sustainable transport	General outcomes	Transport and new mobility solutions
traffic congestion	General outcomes	Transport and new mobility solutions
traffic safety	General outcomes	Transport and new mobility solutions
air pollution	General outcomes	Public realm and natural environment
air quality	General outcomes	Public realm and natural environment
carbon emissions	General outcomes	Public realm and natural environment
crime detection	General outcomes	Public realm and natural environment
crime prevention	General outcomes	Public realm and natural environment
GHG emissions	General outcomes	Public realm and natural environment
waste reduction	General outcomes	Public realm and natural environment
disability support	General outcomes	Health and wellbeing
healthy ageing	General outcomes	Health and wellbeing
better public services	General outcomes	Decision making and institutions
data-driven city	General outcomes	Decision making and institutions
digital public services	General outcomes	Decision making and institutions
inclusive growth	General outcomes	Decision making and institutions
inclusivity	General outcomes	Decision making and institutions

Search term	Term category	Domain (if relevant)
innovative public services	General outcomes	Decision making and institutions
integrated service provision	General outcomes	Decision making and institutions
energy consumption	General outcomes	Critical infrastructure and utilities
energy efficiency	General outcomes	Critical infrastructure and utilities
energy usage	General outcomes	Critical infrastructure and utilities
resilient infrastructure	General outcomes	Critical infrastructure and utilities
water consumption	General outcomes	Critical infrastructure and utilities
water usage	General outcomes	Critical infrastructure and utilities
energy consumption	General outcomes	Built environment
energy efficiency	General outcomes	Built environment
energy usage	General outcomes	Built environment
liveable buildings	General outcomes	Built environment
sustainable housing	General outcomes	Built environment

Source: Frontier Economics.

Quality assurance

We use the keywords in Figure 35 to generate an initial dataset of companies identified through the AI algorithm. We incorporate feedback from a sample of 100 companies to flag those that are relevant for the Connected Places market and set out selection criteria to filter out those that are not:

- **Selection criterion 1:** Companies that match broad technology terms also need to match domain-specific activities and/or outcomes. This is to make sure that these technologies are applied in the Connected Places domains.
- **Selection criterion 2:** Exclude sectors that are not relevant for the Connected Places market such as photography, marketing and advertising, staffing and recruitment, and media production.[63]

Based on this feedback a new dataset was generated. We manually reviewed a sample of another 100 companies in the new dataset to assess the accuracy of the search term and identify false positives.

1. Random sample of 20 companies overall.
2. Random sample of five companies for each of the technology-related terms with the highest counts (35 companies in total).
3. Cross reference with external data sources to check if companies are included in dataset.

[63] Other sectors excluded are Agriculture; Apparel and Fashion; Arts and Crafts; Cosmetics and Toiletries; Gambling and Casinos,

4. Random sample of 15 companies to review if classification of domains is accurate.
5. Random sample of 30 companies to review whether the selection criteria are being applied.

Overall, we found a false positive rate of around 7% in the sample reviewed for the first three exercises, which is in line with what is expected when applying the Glass.ai approach. All the exceptions to the selection criteria are also relevant and should be included in the Connected Places market.

Employment calculation

Our data includes information on employment for 79% of companies. Allocating all 1.8m employees in large companies to Connected Places would be to grossly overestimate the size of the market. Therefore, we have generated three estimates with varying assumptions on the proportion of large firms' employment that is part of Connected Places ("adjustment"). The three estimates have been generated as follows:

- **High estimate:** 1 % adjustment for large companies in the 99th percentile, 5% for those between the 95th and 99th percentile, 10% for those between the 90th and 95th percentile, and 50% for those below the 90th percentile. The result is 45,000 employees.
- **Medium estimate:** 1% adjustment for large companies in the 99th percentile and 5% for the other large firms. The result is 37,000 employees.
- **Lower range:** only 1% of employees in large Connected Places companies work in the Connected Places ecosystem. The result is 24,000 employees.

Our estimates include both full-time and part-time employees. In our analysis on the characteristics and composition of total Connected Places employment, we have taken a conservative approach by using the middle range.

GVA calculation

We estimate that the Gross Value Added (GVA) generated in a year by the 37,000 Connected Places employees in the UK is between £3.3bn and £3.6bn. We do not have GVA data at company level, so we make an estimate by multiplying the number of Connected Places workers by an appropriate benchmark for GVA. We use two such benchmarks in order to get a range:

- For the top end of the range, we assume that all Connected Places employees generate the same GVA per worker as the average in the digital sector (as defined by DCMS). According to the latest data available, this is £99,000.[64]
- For the bottom end of the range, we assume instead that:
  - Connected Places employees in digital sector companies generate £99,000 per worker;

[64] Source: DCMS sectors economic estimates.

- Connected Places employees working for other companies (e.g. utilities, healthcare, transport) generate the same GVA per worker as the average in non-digital sectors. That is £56,000 according to the latest data available.[65]

[65] Ibid.

Annex B ADDITIONAL FINDINGS

Cross links between domains

Figure 36 Number of companies by domain link in the UK

Domain 1	Domain 2	Number of companies
Built environment	Built environment	286
Built environment	Critical infrastructure and utilities	171
Built environment	Decision making and institutions	6
Built environment	Health and wellbeing	5
Built environment	Public realm and natural environment	26
Built environment	Transport and new mobility solutions	15
Critical infrastructure and utilities	Critical infrastructure and utilities	229
Critical infrastructure and utilities	Decision making and institutions	8
Critical infrastructure and utilities	Health and wellbeing	4
Critical infrastructure and utilities	Public realm and natural environment	9
Critical infrastructure and utilities	Transport and new mobility solutions	22
Decision making and institutions	Decision making and institutions	32
Decision making and institutions	Health and wellbeing	5
Decision making and institutions	Public realm and natural environment	4
Decision making and institutions	Transport and new mobility solutions	2
Health and wellbeing	Health and wellbeing	74
Health and wellbeing	Public realm and natural environment	1
Public realm and natural environment	Public realm and natural environment	52
Transport and new mobility solutions	Decision making and institutions	7
Transport and new mobility solutions	Health and wellbeing	3
Transport and new mobility solutions	Public realm and natural environment	29
Transport and new mobility solutions	Transport and new mobility solutions	182

Source: Frontier Economics analysis of Glass.ai data

Cross links between technology categories

Figure 37 Number of companies by technology link in the UK

Technology category 1	Technology category 2	Number of companies
Connectivity solutions	Connectivity solutions	12
Connectivity solutions	Data aggregation for visualisation and insight	2
Connectivity solutions	Data storage and processing	7
Connectivity solutions	Digital twins	1
Connectivity solutions	IoT hardware (incl. sensors)	10
Connectivity solutions	IoT software	2
Consulting, strategy and management services	IoT software	2
Data aggregation for visualisation and insight	Data aggregation for visualisation and insight	4
Data aggregation for visualisation and insight	IoT hardware (incl. sensors)	3
Data storage and processing	Data aggregation for visualisation and insight	8
Data storage and processing	Data storage and processing	6
Digital twins	Digital twins	1
General IoT	Connectivity solutions	25
General IoT	Consulting, strategy and management services	2
General IoT	Data aggregation for visualisation and insight	12
General IoT	Data storage and processing	19
General IoT	Digital twins	9
General IoT	General IoT	35
General IoT	IoT hardware (incl. sensors)	65
General IoT	IoT software	28
IoT hardware (incl. sensors)	Data storage and processing	5
IoT hardware (incl. sensors)	Digital twins	2
IoT hardware (incl. sensors)	IoT hardware (incl. sensors)	7
IoT hardware (incl. sensors)	IoT software	10
IoT software	Data storage and processing	3
IoT software	IoT software	1
Other	Connectivity solutions	1

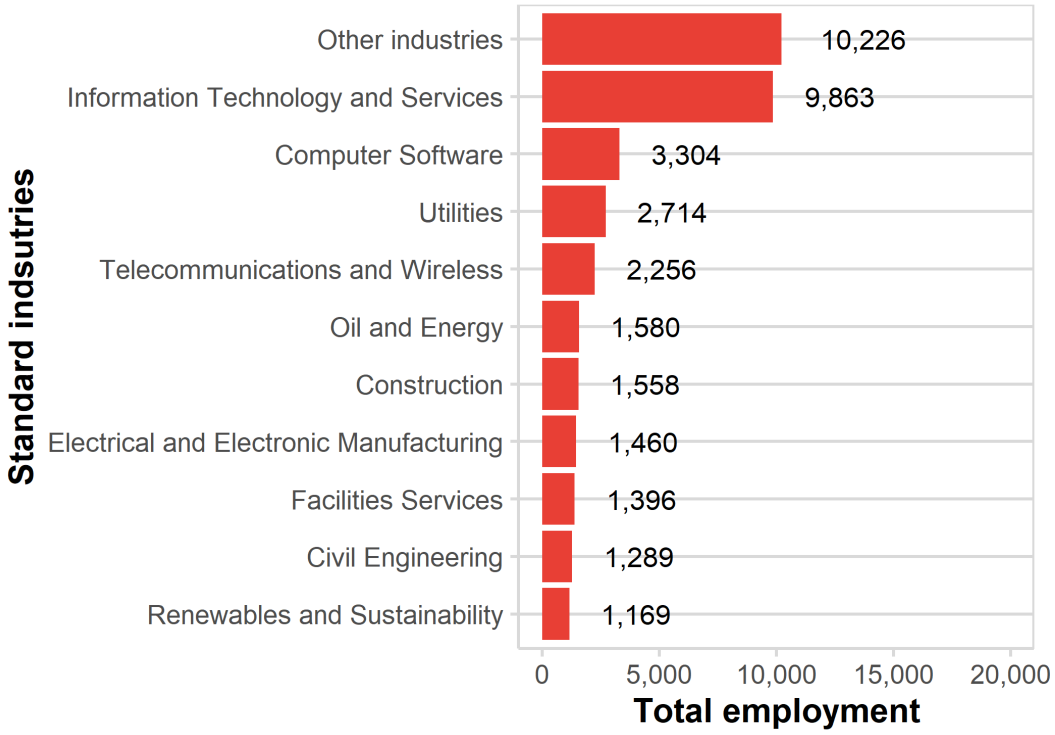
Source: Frontier Economics analysis of Glass.ai data

Distribution of UK Connected Places companies across standard industry categories

Companies operating in the top 10 industry categories employed 75% of people working in the Connected Places market. “Information Technology and Services”

is the largest sector, accounting for around 9,900 of the 37,000 Connected Places jobs.

Figure 38 Estimated total employment by standard industries in the UK



Source: Frontier Economics analysis of Glass.ai data
Note: Standard industries categorised according with Glass.ai classification.

Location of Connected Places companies in the UK

We examine where Connected Places suppliers are based in the UK using location indicators gathered by Glass.ai from corporate websites. Overall, postcodes are available for 58% of companies in our dataset. Figure 39 shows the distribution of companies by region. We can see clear clusters around London and in the South East.[66] They account for 26% and 18% of companies, respectively, or 44% of the total. That is more than the 35% figure for the economy as a whole [67] but Connected Places is less concentrated than the ICT sector, which has 55% of firms in London and the South East.[68]

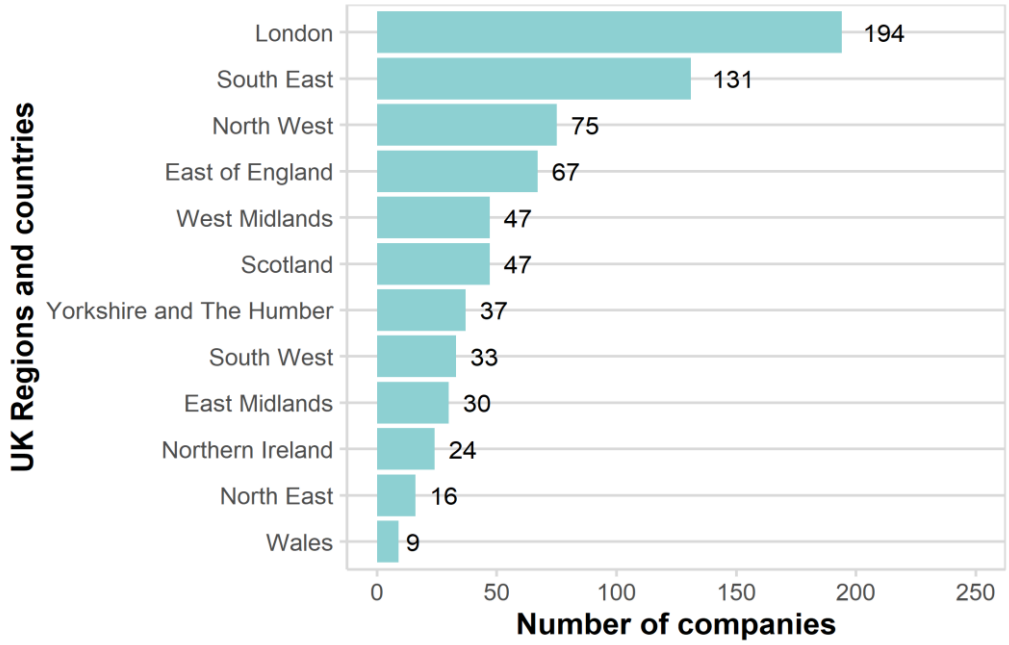
Connected Places companies are spread across the UK, as the map in Figure 40shows. And it is important to note that their activity is not necessarily confined to their home location; they may well be doing business around the country.

[66] Connected Places companies in the South East are located mainly in Milton Keynes (8%), Oxford (8%) and Reading (7%).

[67] Out of 2.7m PAYE- or VAT-registered businesses.

[68] ONS: UK Business, activity, size and location 2021.

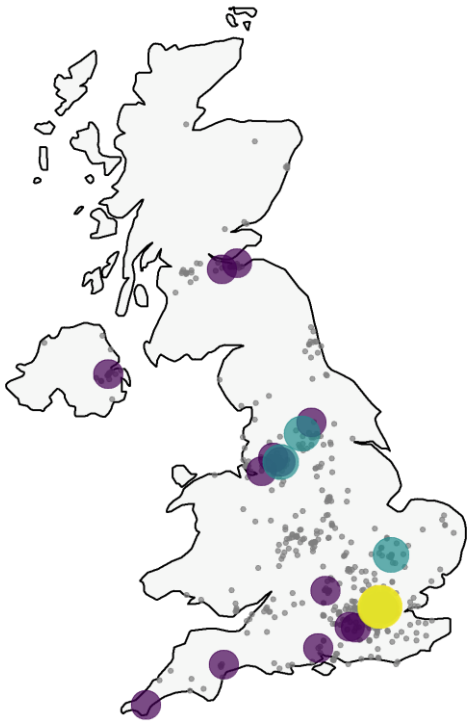
Figure 39 Number of companies by UK region



Source: Frontier Economics analysis of Glass.ai data

Note: Excludes dissolved companies based on Companies House status and non-profit.

Figure 40 Distribution of companies across the UK



Source: Frontier Economics analysis of Glass.ai data

Note: Dot colours represent the number of companies in that postcode area: yellow = 6; blue = 5-4; purple=3-2 ; grey = 1

Location of Connected Places companies compared with other markets

The geographical distribution of Connected Places, Cybersecurity and Geospatial Data firms is broadly the same.[69] In all three cases, market activity is spread across the UK, but London and the South East are home to more companies than the economy as a whole (35%):

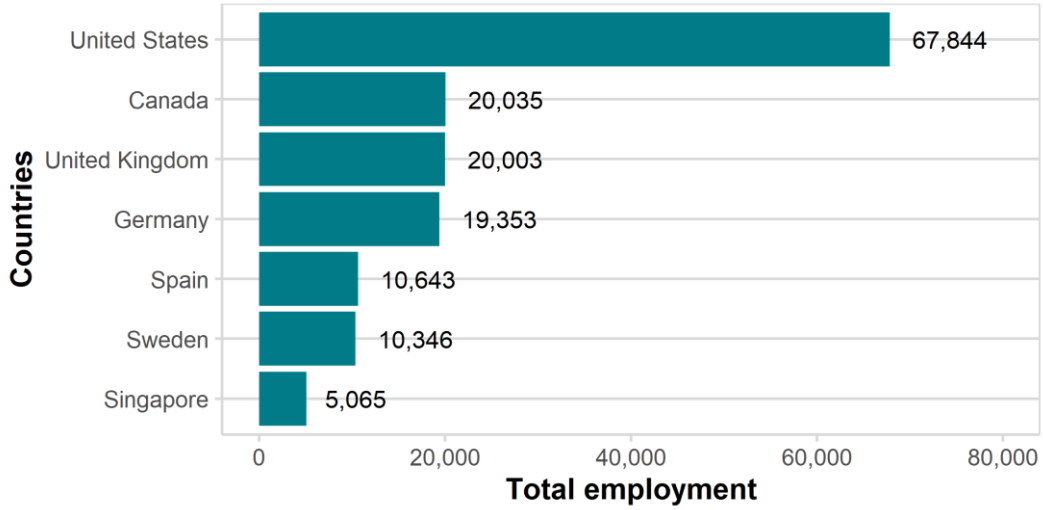
- In Connected Places, 44% firms are based in London and the South East (26% London, 18% South East);
- In Cybersecurity, 50% of firms are based in London and the South East (30% in London, 20% in South East);
- In Geospatial data, 42% of firms are based in London and the South East (28% in London, 14% in South East)

To the best of our knowledge, there is no recent evidence on the geographical distribution of consumer IoT companies in the UK.

International comparison of Connected Places employment

We found a similar distribution of activity across the seven countries in our data. The number of Connected Places jobs as a proportion of overall employment is comparable in the UK, the US, Germany and Spain. Smaller countries (Canada, Sweden and Singapore) punch somewhat above their weight.

Figure 41 Total employment by country



Source: Frontier Economics analysis of Glass.ai data
Note: Employment data based on LinkedIn available figures.

[69] Sources: Cybersecurity Sector analysis 2021; Frontier Economics (2020), "Geospatial Data Market Review".

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