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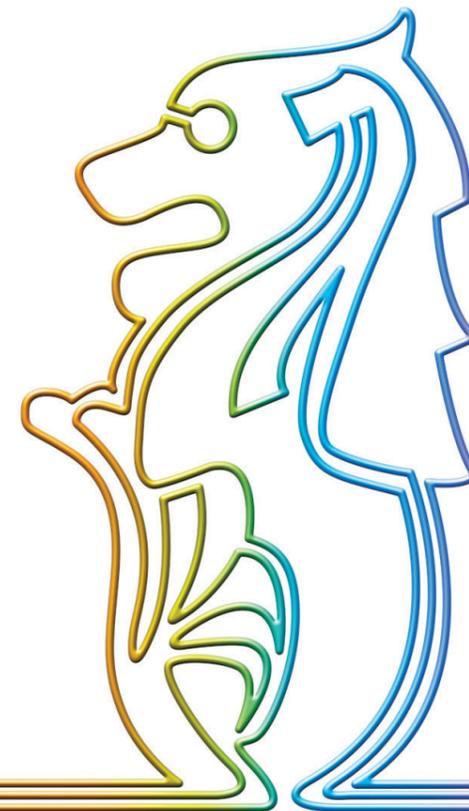
DIGITAL CAPITALS SINGAPORE REPORT

NOVEMBER 2019



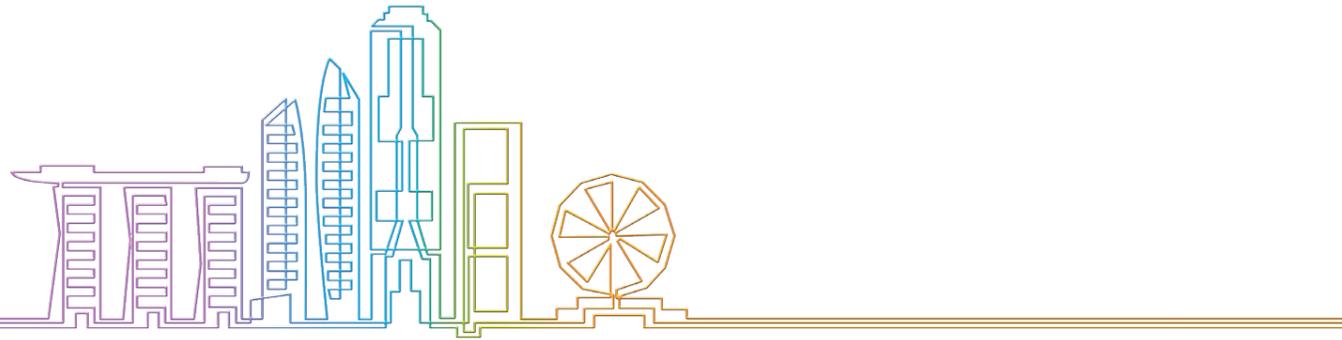
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Introduction



The creation and sharing of data is central to both economic and social activity. However, in recent decades there has been an enormous increase in the rate at which data is created, stored and used for commercial purposes, and for other uses such as in healthcare and entertainment.

The rate at which data is being created continues to grow at astounding rates, driven by data-intensive technologies in business, government and in the home. The growth in data is also expected to be further stimulated by new or evolving data-intensive technologies such as Artificial Intelligence (AI) and the fifth generation of mobile communications technology (5G).

The economic contribution of digital information has previously been termed the 'data economy':¹ the financial and economic value generated by the creation, storage, retrieval and use of highly-detailed business and organizational data at high speeds. The economic contribution of the data economy to national economies has been previously examined in an earlier study also commissioned by Digital Realty (dating from 2018), which focused on the current and potential future size and value of the digital economy in a number of European countries.

The world's leading cities are major hubs for the data economy because they typically have very high densities of commercial activity stimulated by data and digital technologies. This leading role is linked to the concentrations of knowledge-intensive and data-fueled industries, such as financial services, professional

services, and media and communications. Of course, the largest cities are also very often the location for command and control functions for governments, major corporations, universities and other entities.

The leading cities – the digital capitals – also possess some of the world's richest digital skills resources, research and development (R&D) assets, and digital and supporting infrastructures that make it easier for entrepreneurs and skilled workers to share ideas, collaborate and develop new forms of technology and applications.

To explore the status of Singapore as one of the world's digital capitals, Digital Realty has commissioned a new report that quantifies the current and assesses the potential future contribution to the data economy of 4 specific digital technologies: AI; Blockchain; the internet of things (IoT); and 5G. The time period for the future assessment is the period up to 2029.

Main Drivers

There has been a huge increase in data generation over the past decade – driven by advances in digital technology – which have led to the proliferation of connected devices and sensors in both business and household situations. The growth in the rate at which data is being generated currently shows no signs of diminishing, driven by an increasing range of industrial, government and consumer applications. The amount of data generated each day is expected to be further boosted as emerging or fast-growing digital technologies – including AI, virtual reality (VR) and autonomous

vehicles (AV) – become widespread in their usage.

Various predictions of the scale of data generation are available, all of which anticipate continued huge increases in the volume of data production. For example, IDC in 2018 predicted that there is likely to be a world-wide annual growth rate for data generation of 61% per annum (p.a.) up to 2025.²

This global growth is being driven by ever larger numbers of people being connected to digital devices for an increasingly large number of uses and applications. However, it is expected that the creation of data by businesses will become even more important than that by consumers as the number of sensors and devices in industrial, commercial, infrastructure, healthcare, transportation and many other situations increases very rapidly.

The continuing increase in the generation and sharing of data is being further boosted by the emergence and development of 4 interlinked digital technologies: AI; IoT; Blockchain; and 5G.

Digital Capital – Singapore

As one of the world's leading centers for business and finance, transportation, logistics and technology manufacturing, Singapore is a major digital economy hub of global significance. This contribution is underpinned by Singapore's role as one of Asia's leading financial centers, as a major aviation and shipping hub, and as an important location for education, R&D and technology manufacturing. Singapore also benefits from a very large and highly-skilled technology workforce, excellent digital and other communications infrastructure (including global aviation links) and very supportive government policies supporting R&D, entrepreneurship and business innovation.

As highlighted in the Digital Capitals Index, Singapore is currently ranked 6th among the world's leading digital cities. Moreover, Singapore is also predicted to improve its global ranking by 1 place (moving up to 5th overall) by 2024, and to retain its top 5 ranking by 2029.

The scale of the contribution made by Singapore is underpinned by the size and prosperity of the city, with the latter driven to a significant degree by the structure of the city's business base, the entrepreneurship of its citizens and the support from government for technology-focused industries.



An important component of the city's economy and its status as a leading digital capital is the contribution of the financial services sector. Singapore is one of the world's most important locations for foreign exchange and other transactions. The city is also a major headquarters location for many of the world's largest banks and other leading financial institutions.

Technologies such as AI and Blockchain are already important in the provision of financial services (including market trading and in the detection of fraudulent behavior) and their use and importance can be expected to grow very significantly over the next decade or so.

Singapore is a major location for a wide range of professional services industries, including legal and accountancy services, business consultancy services, real estate management services, advertising and media. Singapore is also a very important transport, logistics and communications hub for the Asia-Pacific region, particularly for aviation and maritime transport. All of these industries are at the forefront of the adoption of – and innovation in – digital technologies.

As an important higher education center, with teaching and research specialisms in fields that are central to digital industries, Singapore has a large number of universities and research institutions, including those with specialisms in digital technology, life sciences and healthcare.

Healthcare itself is also an important export industry for Singapore, with the city's hospitals and clinics providing advanced treatments to patients from the wider South East Asia region and beyond.

Singapore is an important center for the design, development and manufacturing of advanced technologies, including aircraft engines, computer hardware and software, communications devices, offshore drilling equipment and other advanced products. Use of digital technology in advanced manufacturing – including AI and advanced robotics – is likely to grow very rapidly over the next decade or so.

¹ Digital Realty: The Data Economy Report, 2018

² <https://www.networkworld.com/article/3325397/idc-expect-175-zettabytes-of-data-worldwide-by-2025.html>

Value of AI, IoT, Blockchain & 5G to the Singapore Economy: 2019

A key part of the growth of Singapore as a digital economy expected over the next decade will result from a set of data intensive, interconnected technologies such as AI, IoT, Blockchain and 5G. With that in mind, the economic contributions of these 4 high-potential, data-led technologies have been examined to provide a baseline against which the future potential for growth in Singapore's data economy can be compared.

The current contribution of the 4 digital technologies to the Singapore economy in 2019 is estimated to be worth S\$12.47 billion, with IoT alone contributing S\$6.38 billion (51% of the total). AI is estimated to contribute a further S\$3.90 billion (31%) while a further 16% of value is contributed by Blockchain (S\$1.94 billion). The current contribution of 5G – as the newest technology – is a comparatively modest S\$0.25 billion.

As a proportion of the overall city economy, the 4 technologies in aggregate are currently estimated to contribute S\$12.47 billion to the overall economy of Singapore, which amounts to an estimated 1.88% of the overall economy.

Technology	Annual value (in S\$ billions), 2019	% of overall city economy, 2019
AI	3.90	0.59%
Blockchain	1.94	0.29%
IoT	6.38	0.96%
5G	0.25	0.04%
Total	12.47	1.88

Table 1: Singapore – Estimated value of the 4 digital technologies: 2019 (S\$ billions, 2019 prices)

In terms of international rankings, Singapore is currently ranked 3rd overall (behind Tokyo and New York City) in terms of the annual value contributed by these 4 digital technologies. Note, some columns or totals may not sum exactly due to rounding of decimals.

Predicted Future Value: 2024

By 2024, the value of the technologies to the annual value of Singapore's economy is expected to have grown to S\$29.39 billion p.a. This represents growth of S\$16.92 billion compared to 2019, which translates into predicted growth of 136%. By 2024, the 4 technologies are expected to contribute 3.59% to the city's overall economy, up from 1.88% in 2019.

In absolute terms, the largest component of growth is expected to be from AI: this segment is expected to contribute S\$12.06 billion p.a. by 2024, compared to S\$3.90 billion p.a. in 2019, representing an annual increment in value amounting to S\$8.16 billion p.a. (which is a proportionate increase of about 210%).

Technology	Annual value (in S\$ billions), 2024	% of overall city economy, 2024
AI	12.06	1.47%
Blockchain	3.90	0.48%
IoT	10.61	1.30%
5G	2.81	0.34%
Total	29.38	3.59%

Table 2: Singapore – Estimated value of the 4 digital technologies: 2024 (S\$ billions, 2019 prices)

However, the most spectacular growth – in proportionate terms – is expected to come from 5G, with real growth in annual value of over 1,030%. This is because, while 5G is currently a newly-emerging technology, by 2024 the use of 5G is expected to be widespread among both consumers and businesses across Singapore.

With respect to international rankings for the annual value contributed by these 4 digital technologies, by 2024 Singapore is expected to maintain its 3rd rank position overall (with Tokyo again in 1st position and New York City 2nd).

Singapore is also expected to be in 3rd position when the specific technologies are considered individually: the exception is Blockchain, where the annual value of contribution in Singapore is predicted to be the 4th largest of any city.



Predicted Future Value: 2029

The overall contribution in terms of value to Singapore's economy of the 4 technologies by 2029 is expected to grow to S\$49.79 billion, representing an increase in real terms of S\$20.40 billion p.a. compared to 2024. The overall increase in annual value when the 2029 predicted values are compared to those for 2024 is expected to amount to 69%. By 2029, the contribution of the 4 technologies to the Singapore economy is expected to increase from 3.59% in 2024 to 5.38% in 2029 (and from just 1.88% in 2019).

Technology	Annual value (in billions), 2029	% of overall city economy, 2029
AI	23.16	2.30%
Blockchain	6.52	0.65%
IoT	10.61	1.49%
5G	9.50	0.94%
Total	49.79	5.38%

Table 3: NYC – Estimated value of the 4 digital technologies: 2029 (US\$ billions, 2019 prices)

Compared to 2024, the largest component of growth is expected to be from AI, with an anticipated increase in the annual contribution of S\$11.10 billion. However, the most significant change is the relative contribution of 5G, which is expected to provide an increase of S\$6.69 billion p.a. (i.e. an increase of 238% compared to 2024 levels).

Overall, in proportionate terms, AI is expected to provide 47% of the increase in annual value (when 2029 levels are compared to 2024 levels), with IoT providing 21% and 5G a further 19%.

Compared to other cities in the global Digital Capitals Index, by 2029 Singapore is expected to be generating the 4th largest annual value from the 4 technologies. This implies that by 2029 Singapore will have slipped 1 place in the global ranking of aggregate annual value contributed by the 4 technologies. The reason for this is that the contribution of Shanghai is expected to grow at an even faster pace than that of Singapore.

Overall Performance: 2019-2029

The overall expected situation with respect to the contribution of the 4 technologies to the economy of Singapore is summarized in the table below. Note, some columns or totals may not sum exactly due to rounding of decimals.

The overall value from the 4 digital technologies is predicted to increase from S\$12.47 billion in 2019 to S\$49.79 billion by 2029. Nearly 52% of the overall predicted increase in value is expected to be contributed by AI, with 5G contributing nearly 25%.

Technology	GVA 2019	GVA 2024	GVA 2029	Total increase in GVA: 2019-2029	% contribution to aggregate growth
AI	3.90	12.06	23.16	19.26	51.6%
Blockchain	1.94	3.90	6.52	4.58	12.3%
IoT	6.38	10.61	10.61	4.23	11.3%
5G	0.25	2.81	9.50	9.25	24.8%
Total	12.47	29.38	49.79	37.32	100.0%

Table 4: Singapore – Annual value of the technologies: 2019, 2024 & 2029 (S\$ billions, 2019 prices)

Conclusions

By any measure, Singapore is a major powerhouse for the world's data economy. Indeed, internationally Singapore is currently ranked 6th (among 60 leading cities) as a world digital capital. Moreover, by 2024 it is expected to improve its position by 1 place (rising to 5th overall) and to maintain this position by 2029.

The current annual contribution of AI, IoT, Blockchain and 5G to the Singapore economy is estimated to be S\$12.47 billion in 2019. Overall, the annual financial contribution of these 4 specific technologies to the Singapore economy is currently the 3rd largest of any city in the world (with only Tokyo and New York City experiencing greater annual contributions).

When we look more closely at how well Singapore is adapting to new data-led technologies, very substantial growth potential can be predicted. Indeed, the predicted annual value is expected to grow massively, to S\$49.79 billion p.a. by 2029. Moreover, by 2029 the annual financial contribution of these 4 specific technologies to the Singapore economy is expected to be the 4th largest of any city in the world.

The enormous increase in annual contribution can be expected to be driven across all leading sectors and industries in Singapore, from financial and professional services to media and communications, technology-focused manufacturing, life sciences, education and research.

By 2029, these 4 technologies in combination are expected to contribute just under 5.4% to the overall economy of Singapore, up from just under 1.9% in 2019. The greatest share of this growth (nearly 52%) is attributable to AI with around 25% also coming from 5G.

The overall contribution in terms of value to Singapore's economy of the 4 technologies by 2029 is expected to grow to S\$49.79 billion, representing an increase in real terms of S\$20.40 billion p.a. compared to 2024.

Recommendations and Opportunities for Businesses

If businesses want to benefit from, and even help increase, the S\$49.79 billion p.a. that AI, IoT, Blockchain and 5G are estimated to contribute to the Singapore economy by 2029, they need to take action today. The economies of digital capitals around the world will only continue to grow, albeit at different speeds depending on a number of factors such as economic and government stability.

For Singapore, it is essential that the city and the businesses associated with it take all the right actions that see this digital capital continue to invest in and take advantage of the new technologies that will help them thrive and grow.

Already, the transport and logistics industry regularly makes use of sensors installed in their vehicles to help schedule maintenance and ensure drivers optimize fuel consumption when out on the roads. Financial services organizations are already using AI-powered fraud detection programs to sift through huge amounts of records and find anomalies quickly, preventing illegal activity. Now is the time to plan how business can harness the potential these innovative technologies are offering.

Provided below are some recommendations that businesses should seriously consider if they are to remain competitive in this rapidly growing technological environment.

Take Advantage of Competitive Digital Platforms

There are as yet unrealized opportunities for businesses that have not yet created adaptable technology platforms that, working with key partners, allow them to deploy each of these specialized technologies to gain competitive advantage:

- The 4 technologies explored are only growing in importance, enabling businesses to create and gain intelligence from their data in ways that have never been achieved before.
- An adaptable technology platform will differentiate a business' agility by reducing the time it takes to connect to partners, providers and markets using the latest technologies.
- This will enable companies to tailor their technology deployments at speed and to meet, and even exceed, their needs in an increasingly competitive environment.

Invest in Talent

This report highlights one key area where investment is crucial: a skilled workforce. It is clear that cities and businesses should incubate and invest in technology talent to ensure they continue to have the skills to operate, deliver and capitalize on innovative technologies.

Major cities are vital in creating and hosting high value and innovative commercial activity through their role as locations for knowledge-driven business clusters. As a result, the high density of business networks in the city means the availability of talent and the presence of key infrastructure is also usually found in those places. With today's new technologies, this can very quickly lead to a major skills shortage and prevent businesses from being able to harness the power of their technology innovations.

Investing in digital apprenticeships and supporting college and university digital training programs is essential to the future success of all digital capitals and especially in Singapore.

Think Urgently About Your Future Technology Strategy

Businesses should continuously invest in upgrading and expanding their technology strategies to stay ahead of business need.

The business that is not ready to take advantage of these technologies is the one that is going to rapidly lose ground against its competitors.

Identify the Partners, Suppliers and Key Players That Should Be In Your Competitive Ecosystem

Cities and businesses having technical networks that can be rapidly and seamlessly connected to a global digital ecosystem is vital to fostering innovation and enabling a wider, global connection.

There is good evidence that major cities like Singapore are likely to be increasingly important in creating and hosting high value and innovative commercial activity through their role as locations for knowledge-driven business clusters or ecosystems.

Ecosystems are geographically concentrated networks of interconnected companies and allied organizations (such as universities and research institutes, financial services corporates and suppliers) operating within a specific industry or sector.

Successful ecosystems are usually characterized by a high volume of interactions. For example, where companies work collaboratively to create competitive advantage, exchange ideas, develop innovative products or processes, and go on to launch joint ventures, a competitive service or new businesses together.

Cities and businesses should incubate and invest in technology talent to ensure they continue to have the skills to operate, deliver and capitalize on innovative technologies.



Appendix

Approach to the Study

DATA ECONOMY RANKINGS

As the first step in the research process of Singapore's data economy, a desk-based review was undertaken of the evidence regarding the business benefits of digital technology. This review also identified potential sources of the latest available data covering the city's business and economic datasets.

Second, a set of potential digital economy indicators was proposed and agreed with Digital Realty. The 10 selected indicators covered the following:

- 1 The overall size of the city-level economy
- 2 The scale of activity of businesses operating in data-intensive business sectors plus the rate of adoption of digital technology among other businesses
- 3 The scale of consumer demand for data and digital applications
- 4 R&D: the presence of a leading university or universities in the city
- 5 The quality of telecommunications infrastructure
- 6 Human capital: the proportion of workforce with advanced data skills
- 7 The stability of the local political environment, levels of crime and other metrics of governance
- 8 Quality of life indicators, such as the quality of health, public education, the efficiency of public transport and environmental indicators
- 9 Support for the data sector such as through open data policies
- 10 The quality of the environment for business (i.e. the ease of doing business, including for international companies)

Development Economics gathered quantitative data relevant to each family of indicators, as far as possible using single sources to facilitate consistent scoring and ranking on each indicator.

Future predictions of the absolute and relative rankings for the data economy were also developed in the study. These were developed by harnessing information on – amongst other things – the expected trajectories of

change with respect to the size and structure of the city's economy; demographic and labor market forecasts; expected trajectories of growth in digital adoption by both businesses and consumers; recent trends in performance of universities; and trends in digital infrastructure provision.

CONTRIBUTIONS OF THE 4 TECHNOLOGIES

Apart from ranking the current and potential contribution of Singapore as a digital capital, the study also quantified the current and potential future economic contribution – in the form of GVA – of the 4 specific digital technologies: AI, IoT, Blockchain and 5G.

The approach taken to producing current estimates involved the gathering and analysis of information on the size, structure and productivity of the business sectors and workforces operating in the digital economy of Singapore. The quantification of future predicted estimates of contributions harnessed a range of forecasts, both for the economy and labor market, but also the likely rates of adoption of each digital technology by the city's business base, its public sector and the householder population of the city.

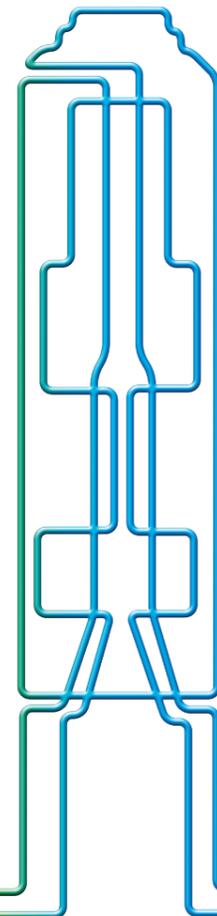
Indicators and Data Sources

The information is constructed by gathering the most recent available data for 10 families of indicators of the current economic, business, demographic, infrastructure and other characteristics that influence the scale and level of participation in the modern digital economy. More details on each of the criteria and the indicators used are provided below.

SIZE OF THE ECONOMY

The first criteria used is a measure of the overall size of the city's total economy. This is measured in terms of the scale of economic output (GVA) produced by the city annually, with adjustments made to reflect productivity and local currencies using a purchasing power parity approach.

Data on the human and business population in the city, plus the annual value of production per capita was then used to estimate the current annual value of economic activity taking place.



BUSINESS DIGITAL ADOPTION AND ECONOMY

This criterion is a blended indicator that considers several aspects that relate to the extent to which digital technologies are important to the economy of the city.

- First, the score considers the extent to which digital technologies have been adopted by all businesses and other employers (including government organizations) in the city.
- The second aspect that was covered is the estimated extent of the take-up by businesses and public agency users of the 4 digital technologies (AI, IoT, Blockchain and 5G) included in this study.
- The third aspect is the extent to which companies that are part of the supply chain for digital technologies are locally present in the city. This was taken into consideration through estimation of the annual value of delivery of digital technology services by supplying businesses located in the city.

CONSUMER DEMAND FOR DATA

Having considered the supply side, the third indicator considers the demand for data on the part of the city's urban population. This is based on the estimated annual per capita demand for digital data multiplied by the estimated size of the city's population. The demand for data considers a number of sub-indicators, including number of mobile phone subscriptions; fixed broadband data usage; and social media usage.

HIGHER EDUCATION + OTHER R&D ASSETS

This indicator involved the gathering of information on the scale, quality and relevance of the research and teaching resources available at universities and other higher education institutions in each urban area. If specialist research institutes relevant to any or all of the 4 digital technologies were known to be present in the urban area, this was also reflected through a manual upwards adjustment to the city's scoring. Essentially, scores were awarded for the scale (e.g. number of students, value of research grants awarded) and quality of the research and higher education institutions located in each urban area.

DATA INFRASTRUCTURE

This indicator takes account of the estimated capacity and efficiency of the city's fixed and mobile data infrastructure. This was assessed using current data on average mobile and fixed broadband data download speeds.

HUMAN CAPITAL

This indicator considers the size, skills and qualifications of the city's working age population. There are two aspects included within the scoring and ranking process:

- Firstly, there is a general assessment of the qualifications of the city's working age population, considering the proportion and size of the workforce that is educated to degree level or equivalent, and also considering the proportion (and number) of workers that have no qualifications.
- The second aspect considers the proportion and size of the workforce that are 'digital workers' (i.e. the number of workers) and proportion of the workforce that are IT professionals (covering occupations such as computer systems designers and analysts, software developers, database administrators, information security analysts, etc.).

GOVERNANCE

This is a measure of the efficiency of municipal governance provided in the city, including aspects such as crime rates, corruption levels, etc.

QUALITY OF LIFE

This criterion considers the ability of the city to attract and retain technology-based businesses, investment and skilled workers in 'knowledge economy' industries such as information and communications services, professional services and digital media. This is assessed by producing an overall score based on a range of quality-of-life based indicators, such as the quality of the city's primary and secondary education and public health systems, the efficiency of the city's public transport system, and the quality of the city's environment (based on air quality readings).

DATA OPENNESS

This indicator is different to those described above in that it applies to the national level rather than the specific city. Essentially, the score applied to the city is the national score achieved for data openness in the current edition of the open data barometer (ODB). This score reflects national policies with respect to the availability of government business datasets and other types of data.

BUSINESS SUPPORT ENVIRONMENT

This measure provides an indication of the perceived ease of doing business in the city. The key component parts of this assessment are considered to include the business and personal tax burden, openness to inward investment and property ownership, policies with respect to international movement of digital industry talent, other skilled workers and entrepreneurs, intellectual property protection and levels of corruption.

Because many of these factors are mainly influenced by national policy it was decided to use a single national ranking.

Glossary of Terms

Term used in report	Explanation
5G	The fifth generation of mobile network connectivity, expected to deliver significantly improved levels of network reliability, considerably faster data transfer speeds and improved performance with respect to latency.
Artificial Intelligence (AI)	A range of rapidly evolving computer-based technologies used by machines and devices to simulate elements of human behavior such as sensing, learning, reasoning and decision-making.
Blockchain	Blockchain is an electronic transaction-processing and record keeping technology that benefits users by decentralizing the way that information about transactions is shared. Blockchain provides users with a method of tracking information and transactions securely and by eliminating the need for third-party verification.
Clusters / Ecosystems	Clusters / ecosystems are geographically concentrated networks of interconnected companies and other organizations (such as universities, research institutes and public agencies) operating within a specific industry. Successful clusters / ecosystems are usually characterized by a high volume of interactions and collaborations between businesses and other cluster / ecosystem participants.
Data Economy	The financial and economic value created by the storage, retrieval and analysis via software and other tools of very large volumes of business and organizational data at high speed.
Gross Value Added (GVA)	GVA is defined as the net value contributed to the economy by a company, industry or other economic entity. This includes compensation of employees, company profits and contributions to the Exchequer.
Internet of Things (IoT)	A system of assets or devices that are fitted with a sensor producing data that is stored and available for analysis that can be used to deliver production efficiencies or other improvements in the way the system operates. For example, sensors on machines that can be used to predict the need for maintenance or use of spare parts before the machine fails and production time is lost.





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