ICAEW THOUGHT LEADERSHIP
BUSINESS AND MANAGEMENT FACULTY

The internet of things and accounting: lessons from China

Contents

Summary: the internet of things and accounting – a powerful combination

The internet of things and accounting both help us manage a business from a distance. Using these tools we do not have to be physically present to sense the flow of products through a factory or understand their costs. Combining the internet of things (IoT) with accounting has the potential to provide a powerful means of making organisations more effective. In theory we can improve the management of people, assets and risks, we can better forecast future performance and we can make better decisions. It could be argued the IoT provides the opportunity for a breakthrough in management accounting. However, there are significant concerns about the ethical use of data produced by the IoT and IoT security. Malicious actors can damage vital infrastructure – what can be managed from a distance can be attacked from a distance. We urge accountants to embrace the opportunities provided by the IoT while working to address the issues.

The IoT includes computing power and sensors embedded in everyday objects which can communicate with each other and centralised computers. These technologies enable automation and improved analysis and decision-making based on the data generated. In order to function effectively the IoT depends on complex interrelationships between the various organisations and institutions that develop, use and regulate it.

This report provides a wide-ranging discussion of the nature of the IoT and its potential impact on management and accounting. We also discuss how accountants can acquire the skills they may need to make the most of the IoT, and the risks the IoT poses. Our purpose is to raise IoT awareness among finance professionals so they can explore the possibilities.

The report was developed in partnership with the Shanghai National Accounting Institute and Inspur. The content draws on interviews with Chinese businesses, relevant literature and conversations with ICAEW members. For a number of reasons China is at the forefront of developing and using the IoT and so it provides a fruitful context for our research. This research builds on our report *Big data in Chinese businesses*.

The evidence from our interviews and literature review shows the IoT could help improve accounting and management in a range of areas, including:

- data quality (which underpins many of the other improvements);
- transaction processing;
- asset, revenue, cost and risk analysis;
- product quality; and
- employee performance.

Taking advantage of these improvements should lead to better planning, decision-making and business performance. There will also be opportunities to develop new strategies and business models.

At the moment, the main IoT benefits flow through to the finance department from the use of the IoT in operations, rather than the finance department driving implementation or using the raw data directly. But as the IoT ecosystem develops, accountants will see opportunities to get more involved at both the operational and strategic levels. This will include helping to address several IoT challenges, such as security and privacy.

In order to grasp the opportunities presented by the IoT, accountants will need to develop their knowledge, skills and attitudes. Some may decide to develop their statistical and analytical skills so they can get involved at a detailed level, while others may settle on a high-level understanding. This will in part depend upon role, seniority and how best to collaborate with IoT specialists and data scientists.

We believe data from the IoT, along with other forms of big data, could be used to expand the boundaries of accounting and enable accountants to add more value to organisations. The opportunities are clear and accountants need to embrace them.

Background to the project and research approach

THE BIG DATA AND ACCOUNTING RESEARCH CENTRE

This project has been undertaken by the Big Data and Accounting Research Centre, which was formed in 2016 by ICAEW, the Shanghai National Accounting Institute (SNAI) and Inspur. In 2018, the centre produced its first report, *Big data in Chinese businesses*. The report explained how China is in a strong position to generate and exploit big data, but that there are significant organisational barriers in realising value from big data. The report also argued accountants can play a stronger role around big data, especially in data governance.

PROJECT RATIONALE

We wanted to build on the initial report and go into greater depth on a topic which offered the possibility of innovation in management accounting. Since 2013, the Chinese Ministry of Finance has placed significant emphasis on developing management accounting as a means of improving organisational performance. In this context our partner, Inspur, pointed out the IoT was growing rapidly and some finance teams were using IoT data in interesting ways. An exploratory survey carried out by SNAI, summarised below, supported this view. Our literature review confirmed the rapid growth of the IoT and provided a wide range of business use cases. However, the literature rarely mentioned the use of IoT data by accounting and finance teams. Therefore, we felt we could contribute to the development of management accounting and finance departments by highlighting the opportunities provided by the IoT.

SNAI SURVEY SUMMARY

SNAI's exploratory survey asked Chinese companies about their use of the IoT in general and its use in management accounting in particular. Of the 211 respondents, 42 (20%) – mainly in the manufacturing, finance and IT sectors – were using IoT technologies. The main uses were in procurement and supply chain management, process and quality improvement and financial management. Within these areas the general applications were in control, forecasting and planning, decision-making and performance evaluation. Management accounting applications were also in evidence, with the most frequent responses relating to general operations support, cost control, transaction processing and risk management. However, 12 of the 42 companies using IoT technologies were finding it difficult to integrate the IoT into finance processes. Generally, respondents felt the IoT was having a positive impact on performance, governance, culture and, where applicable, financial management.

For those companies not using the IoT, the main barriers were insufficient management attention, costs and the nature of the industry. However, just over half of these companies were planning to use the IoT in the future.

PROJECT APPROACH

We met with seven Chinese companies that were playing leading roles in the use of the IoT. At four of these companies, we spoke with senior managers from IT and operations who had broad knowledge of how the IoT was being applied; and at three of the companies, we spoke with senior finance professionals. The meetings enabled us to explore the potential benefits and the future impact of the IoT on accounting and finance departments. We have supplemented the examples obtained from the interviews with examples from the literature. Clearly, using this approach, we cannot assess the extent of IoT data usage in finance.

What is the IoT?

A BRIEF HISTORY OF THE IOT

The first use of the term 'the internet of things' is usually credited to Kevin Ashton, a British technology pioneer. He used it in a presentation he gave to Procter and Gamble in 1999. He was interested in capturing data about the world without the need for humans to obtain or input it, eg, through typing.[1] While the term is relatively new, the technologies involved in the IoT have been around for much longer: in 1982 students at Carnegie Mellon University connected a Coca-Cola machine to a forerunner of the internet. However, the IoT only really started to take off after internet use and mobile connectivity became widespread, computer processing power and storage became cheaper and sensors improved.

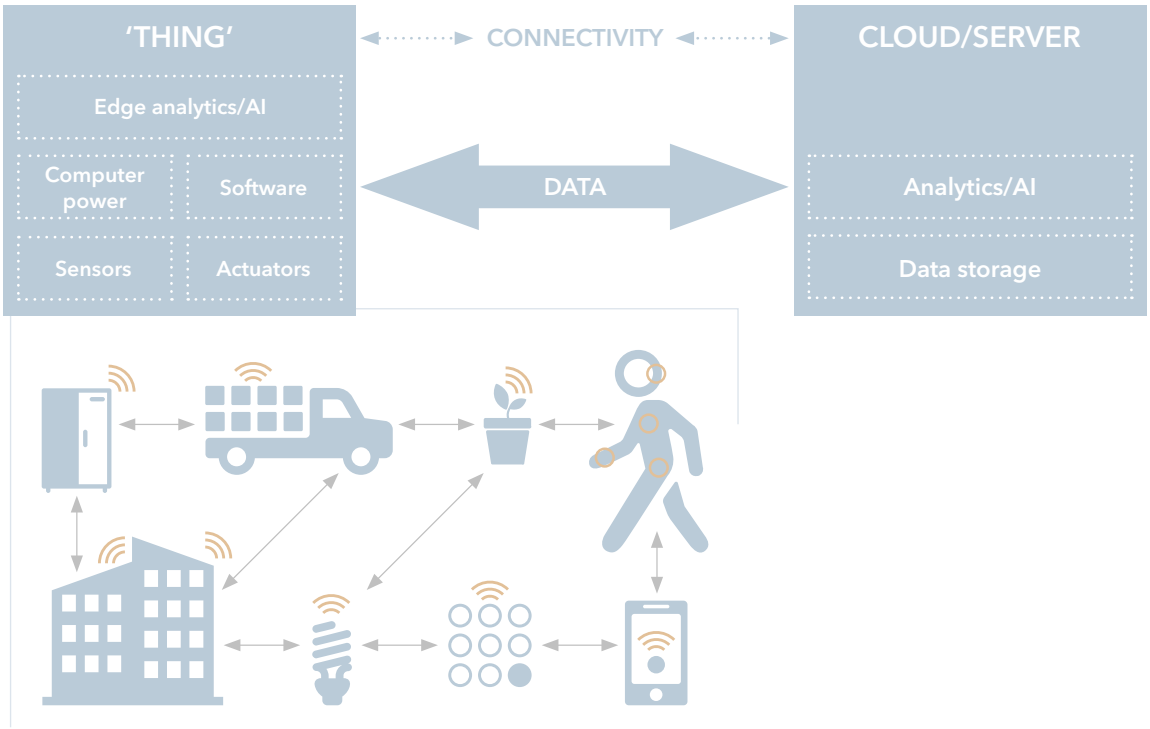
A DEFINITION OF THE IOT

A helpful definition, based on the relevant Wikipedia article (accessed on 5 March 2019), is 'the Internet of Things (IoT) is the network of devices such as vehicles and home appliances that contain electronics, software, sensors, actuators, and connectivity which allows these things to connect, interact and exchange data. The IoT involves extending internet connectivity beyond devices such as smartphones to any range of physical devices and everyday objects. Embedded with technology, these devices can communicate and interact over the Internet, and they can be remotely monitored and controlled.'

It is worth noting that one interpretation of the Chinese characters used to talk about the IoT is 'internet everywhere'.

The following diagram provides a simplified representation of the IoT. Organisations will clearly need to develop their own, more detailed representations to help them explore and implement IoT programmes. We hope our discussion and examples will help with this process.

INTERNET OF THINGS



[1] Ashton, K., 'That "Internet of Things" Thing', *RFID journal*, 22 June 2009.

TECHNOLOGIES INCLUDED IN THE IOT

The technologies that can be integrated into objects such as industrial machines and consumer products include:

- sensors, which can measure and generate data on many variables, including location, vibration and temperature as well as some variables that go beyond what humans are able to sense, eg, the chemical composition of substances;
- video cameras;
- actuators, which can move or control a mechanism enabling the automation of tasks, such as switching a machine off or opening a valve, based on sensor data;
- transmitters and receivers, which enable the broadcast and receipt of messages and data – these include radio frequency identification (RFID) tags, which are like barcodes but can be read automatically from a distance and without line of sight. Tags can be either passive, only activating when in range of a reader, or active, broadcasting a signal periodically; and,
- computer chips, which enable data processing within the device – this is known as edge computing.

In order to form the IoT these technologies require a means of connecting to each other and to the cloud or private servers. This can be via wired connections, Wi-Fi or cellular technologies (2G, 3G, 4G and 5G), with some of these being specifically adapted to the needs of the IoT – eg, low-power wide-area networks. The software, both in the cloud and at the edge, used to analyse and act on IoT data can also be considered part of the IoT technical infrastructure.

One simple use is worth mentioning here to show how the technologies can be used. Sensors placed on a factory machine to monitor variables, such as vibration and temperature, enable several outcomes. If vibrations exceed a threshold, the machine can be automatically switched off by an actuator to avoid damage. The machine could also communicate with a backup machine to switch it on and could send an alert to an engineer's mobile phone. Operators in a control room, potentially thousands of miles away, could use data from the sensors to assess the machine's performance and then remotely adjust its settings. And the ongoing stream of vibration data can be used to build predictive models to schedule preventative maintenance.

It is difficult to draw a clear boundary between interrelated technologies that should and should not be included in a definition of the IoT. Mobile phones, robots, driverless cars and so on all get mentioned in IoT discussions. It could be argued any connected object that can generate data without conscious human input through a keyboard or voice is an IoT device. But as one of our interviewees said, 'I am not particularly interested in definitions; I am interested in solving business problems.' We will approach this report in the same spirit.

China's leading role in the internet of things

THE IOT MARKET AS A WHOLE

While statistics on the size of the IoT market, its growth and the number of connected devices are not difficult to find, making sense of them is another matter. Unclear definitions, undocumented assumptions and varying forecast methods make for a confusing picture. The most widely quoted statistic is from research firm Gartner, which predicted there would be over 20bn connected devices (excluding mobile phones, tablets and PCs) by 2020, from a base of around 11bn in 2018.[2] The figures from market researchers IoT Analytics are much lower. They predict there will be 9.9bn connected devices in 2020 from a base of around 7bn in 2018.[3] Clearly the industry analysts would benefit from bringing some accounting rigour to bear! To put these figures in some perspective, in 2018 the global population was 7.6bn and it is predicted to grow to 7.8bn by 2020,[4] and the number of mobile phone subscribers reached the 5bn milestone in 2017 and is predicted to reach 5.9bn by 2025.[5]

CHINA'S LEADING ROLE IN THE IOT EXPLAINED

It is probably safe to say China makes up a significant proportion of the IoT market, although authoritative statistics are difficult to obtain. China's leading role in the IoT can be explained by several factors:

- The size of the economy and population provides a ready market for IoT technologies.
- Chinese consumers are keen adopters of new technologies, as demonstrated by the rapid spread of mobile payments.
- Central and local governments are investing in the IoT through smart city, safety, crime prevention and surveillance programmes.
- China's government supports IoT development through incentives and political and industrial policies, such as the Belt and Road initiative, the Made in China 2025 initiative, the latest Five-Year Plan (2016 to 2020) and the Internet Plus Action Plan 2015.
- A strong governmental role also enables IoT standards to be set more easily than elsewhere, facilitating better interoperability and communication between devices.
- Chinese companies dominate the manufacture of IoT technologies,[6] even if many such products carry non-Chinese brands.
- Through companies such as Huawei, China also plays a leading role in connectivity infrastructure, including the development of 5G, which is seen as a major factor in extending the reach and uses of the IoT.
- International companies that recognise China's important role in IoT development are partnering with Chinese institutions to set up research centres and advanced manufacturing facilities, such as US conglomerate General Electric's China Advanced Manufacturing and Technology Centre in Tianjin and German industrial manufacturing company Siemens's 'most advanced factory in the world' in Chengdu.[7]
- Chinese universities play their part, with a significant number developing IoT-related courses, and there is even a 'school' at Jiangnan University dedicated to the IoT.
- In terms of IoT patents filed and patents granted, China leads the way, filing over 50% of all IoT patents in 2018.[8] However, some caution is required as high numbers can be achieved at the cost of quality, and filings may be in China only, rather than global.

The state-run English-language press, such as the *People's Daily*, run regular stories on IoT uses and developments, which again indicates the level of state support. The government sees the need for China's manufacturing sector to continue to modernise and save money, given increasing labour costs, while also moving up the value chain to create higher-paying jobs. China is also seeking to lead the world in artificial intelligence, which is dependent on more and better data which the IoT helps to provide.

When considering this national focus on the IoT and the many initiatives in train, it is worth bearing in mind Chinese investment in the IoT has come relatively late. Therefore, while the scale of the Chinese IoT is large, the degree of penetration of the IoT in Chinese industry is probably lower than in some OECD economies such as the US, Japan and South Korea. There are also recent concerns that commercial investment in the Chinese tech sector has peaked and some retrenchment will be necessary.[9] SNAI are clear that the development of the IoT in China still has a long way to go.

We should also note a key challenge to China's continued leading international role in the IoT ecosystem is its ability to garner trust. The international concerns, founded or unfounded, surrounding Huawei's role in 5G infrastructure and links to the Chinese government illustrate how distrust can hamper international expansion.[10]

Ecosystems, the internet of things and accounting

An ecosystem is a useful metaphor for thinking about the IoT, and the term was frequently used by our interviewees. Ecosystems were discussed both in the sense of the IoT as a technology platform and the interrelationships between people, organisations and institutions involved in the IoT. Picturing the IoT as an ecosystem helps us consider the breadth and complexity of the relevant relationships which are often non-linear and multifaceted. For example, as the number of devices grows, data bandwidths improve and costs come down, the volume of data expands, which enables advances in artificial intelligence. However, the pace of growth is constrained by factors such as a lack of people with the necessary skills and fragmented technology standards.

Biological ecosystems are characterised by both collaboration and competition. We see this in the IoT when organisations such as Inspur collaborate with other tech firms in developing standards and IoT platforms, compete with them for customers and depend on the same suppliers. Whether to collaborate or compete is an important strategic tension: should an organisation attempt to develop its own IoT platform and try to get a lead, as Alibaba has done, or join an existing platform and gain a competitive advantage in another way? We are also led to consider what will enable the ecosystem to thrive, such as greater trust in the IoT, and what may undermine it, such as organisations abusing the data collected from IoT devices.

Accounting for ecosystems is in its infancy, with its focus remaining on individual entities. There are accounting rules for legal structures such as joint ventures, and some organisations use open-book accounting to help with supply chain management. However, working out how to account for the value in less formal and more complex relationships requires significantly more work. Such work is important to help organisations decide how to participate in the ecosystem and what value is being realised through such participation.

While the ecosystem metaphor is useful in moving us beyond simpler, linear notions such as supply chains, all metaphors have their weaknesses. Likening the IoT ecosystem to a biological ecosystem for example would underplay the importance of conscious choice and forward planning. Organisms in ecosystems are linked by physical proximity, but the IoT enables interactions without geographical constraints. Any metaphor is a way of seeing but also a way of not seeing – metaphors such as machines, cultures or political arenas would highlight different facets of the IoT.[11]

The role that accounting and accountants might play in the IoT ecosystem is discussed throughout this report. And it is worth noting the IoT is also relevant to the interrelated 'ABCD' of technologies ICAEW has identified as having the potential to transform the accounting profession. The A of artificial intelligence is fed by the D of data, much of which could come from the IoT. And the B of blockchain is seen as a solution to some of the C of cyber issues presented by the IoT.

Accountants could choose to play on the periphery of the IoT ecosystem. However, our hope is this report will encourage accountants to become collaborative partners in making the best of the IoT for businesses, economies and society.

The IoT and accounting as tools for managing at a distance

COMBINING ACCOUNTING AND THE IOT TO MANAGE AT A DISTANCE

Accounting and management information have long helped us to manage multiple organisational entities from a distance, be it from an office across town or a headquarters the other side of the globe. Some have argued the existence and management of large, geographically dispersed firms would not be possible without accounting. For example, Johnson and Kaplan reason that between 1903 and 1915, US explosives firm, Du Pont Powder Company's 'management accounting system mitigated many bureaucratic problems that might afflict a centrally managed, complex integrated business firm.' (p67) They further state, 'The multidivisional structure and management accounting procedures that General Motors' top management devised in the early 1920s enable giant industrial firms to overcome the inefficiency and bureaucratic disabilities that economists once thought were endemic to large-scale organizations.' (p117)[12]

Of course, in managing at a distance, the level of management intervention will vary. At one extreme distant managers may rely on providing high-level guidance, financial targets and incentives. At the other they may use more detailed information to make operational decisions – for example, setting prices or daily output quotas. Clearly, modern communication technologies such as smart phones, email, instant messaging and video conferencing can support managing from afar. But the IoT takes the possibilities to a new level.

If, and it is a big if, distant managers have more knowledge and business acumen than those on the ground, then the quality of decision-making may be improved if those managers have access to the same local information. IoT sensors and CCTV make this feasible in a wide range of cases, eg, monitoring factory throughput or human performance. Indeed, in some areas physical presence may make no real difference, because sensors are required to understand what is going on inside machines, pipelines or people's bodies. Furthermore, where assets and people are geographically dispersed or on the move, human oversight is only possible periodically, whereas the IoT enables constant monitoring. When periodic oversight does take place, it may not be at the most important time – knowing deliveries have been delayed when the lorry returns is less valuable than being able to manage customer expectations as soon as there is a potential problem. Also, with planned visits managers may not see what is really going on if staff make special preparations.

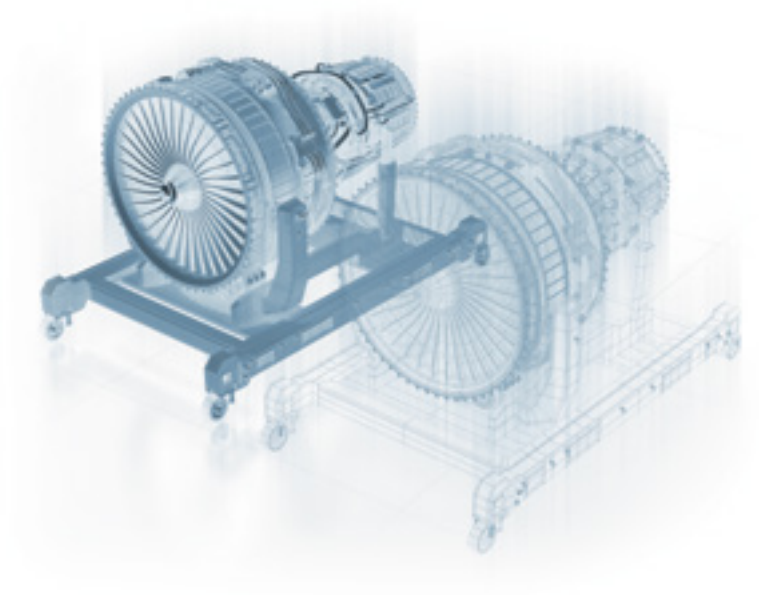
The IoT can support and build on the factors that have made accounting successful in managing from a distance. Accounting enables the conversion of disparate data sources into a common, monetary language; working hours become costs, products sold become revenues and so on. The common language of accounting enables comparability between different units and the consolidation of information at various levels of analysis, eg, cost centres, profit centres, projects, customers, geographies, business units and whole groups of distinct companies. Standardised accounting information is comparable across time and can be forecast. Controls for completeness and accuracy, including the inbuilt control of the double-entry system, are mature and well understood. Therefore, managers can confidently use various cuts of information to look for patterns, ratios, variances and trends to help them make decisions – for example, to close under-performing stores or to increase investment in successful ones. These decisions are sometimes based purely on financial measures.

However, for more refined decisions, we need to understand the causes of performance. To achieve this, financial information has always had to be supplemented with non-financial information. Customer satisfaction, local product preferences, competitor activity and so on could all impact performance and highlight ways to save an underperforming store rather than closing it down. Linking IoT information to financial information increases our ability to make these causal connections. For example, differences in sales revenues between stores can be analysed against IoT data from sensors and cameras monitoring footfall, queuing times, stock-outs, cleanliness, parking availability and, potentially, emotional responses of staff and customers.

We should also note traditional accounting information is often dependent on a transaction taking place. This means many potential sources of insight are lost and many costs are hidden. The IoT can fill some of the gaps – for example, footfall not converted into sales. Even small retail stores have improved sales by using cheap sensors to measure the impact on footfall of different messages on blackboards and window posters.[13]

DIGITAL TWINS AND MANAGING AT A DISTANCE

Digital twins are another example of how the IoT can facilitate managing at a distance. A digital twin is a computer model of a physical asset, such as a piece of equipment, a factory, a mine or a store, which can be viewed in near real time anywhere in the world. This goes beyond a simulation, because the IoT can feed live data from sensors in the actual equipment. This enables operators to see the impact of operating conditions and take immediate action.[14] Such actions can be taken remotely by sending instructions to actuators. The visualisation of a digital twin, maybe using virtual or augmented reality systems, could perhaps be usefully overlaid with financial data to aid decision-making.



THE IMPORTANCE OF PHYSICAL INTERACTION WILL REMAIN

While the IoT, together with accounting information and communication technologies, may lead to increases in managing from a distance, there will still be the need for informal social interaction, face-to-face meetings, site visits,[15] and so on. These are still important for building productive relationships, motivating teams and dealing with conflict. The combination of data from sensors, CCTV and accounting reports cannot pick up everything and can be tampered with. Placing too much trust in distant monitoring and data is as risky as not trusting data enough. Moreover, the insights and intuitions produced by combining what we receive through our five senses while physically present will often be very different from those gained through interpreting video, abstract visualisations, data tables and text.

It is clear the IoT does not fully overcome Chapman's 1997 argument that increasing uncertainty and incomplete quantification mean '... decisions can no longer be taken and actions can no longer be chosen at a distance via the abstract language of numbers. Operational considerations must to some extent be involved in the decision process, not coded, but in their original form.' (p202)[16]

Taking all the above into account, organisations will need to work out how the IoT should affect the balance between what is managed locally and what is managed at a distance based on their own unique circumstances.

IoT as a means of improving data quality

In the *Big data in Chinese businesses* report, we highlighted the importance of data governance, which can help organisations deal with issues of data quality and the problem of 'garbage in garbage out'. The IoT can also help address many such issues. Indeed, much of the impact of the IoT on management and accounting derives from improvements in data quality.

In the table below, we set out the main criteria of data quality and compare dependencies (what you need to rely on) in meeting these criteria when, for example, measuring oil levels in a tank by the human use of a dip stick versus IoT sensors.

DATA QUALITY CRITERIA AND THE USE OF HUMAN EYE VERSUS SENSORS IN MEASURING OIL LEVELS

Data quality criteria	Human dependencies	IoT dependencies
Accuracy	Human eyesight, correct procedure	Accuracy of sensor, correct fitting
Frequency	Each time operative visits	Broadcast frequency which can be constant depending on power and connectivity
Timeliness	Each time operative reports back and inputs data	Broadcast timing which can be real-time depending on power and connectivity
Objectivity	Operative may be dishonest or unconsciously biased	Sensors can be tampered with
Verifiability (audit trails)	Operator discipline in inputting comprehensive data	Automatic logging, eg, time stamping
Reproducibility (reliability)	Human eyesight, correct procedure, consistency among different operators	Accuracy and reliability of sensor (sensors can deteriorate over time and become faulty)
Validity – measures what purports to measure rather than using proxies	Included for completeness – see note below	Included for completeness – see note below
Detail/granularity/precision	Human eye and dipstick gradation	Sensitivity of sensor
Uniqueness/novelty	Dependent on what human senses can assess at same time, eg, viscosity, foreign bodies	Multifunction sensors or multiple sensors
Comprehensiveness/scope of coverage	Sample basis may be necessary given time constraints	All oil reservoirs/tanks with sensors fitted

Note re validity criteria: Often the IoT helps us to measure what we want to measure rather than rely on proxies. For example, as highlighted by one of our interviewees, the power consumption of machines is sometimes estimated using the manufacturer's specifications, but sensors can measure actual power consumption under different conditions and usage patterns.

The importance of data quality and improvements in measurement should not be underestimated. Advances in natural sciences have been supported by more and more detailed measurement, and GPS technology relies on very accurate timekeeping through atomic clocks.[17] In business, internet marketeers are able to measure the impact of small changes to wordings or colours on website click-through rates. The implications for management and accounting from IoT-driven improvements in data quality are yet to play out but could be profound.

Accounting-related IoT use cases

THE BROADER CONTEXT OF IOT USE CASES

The IoT is already being used in many different ways with new uses announced frequently. Major benefits are expected in many sectors. In healthcare the IoT can support remote monitoring of health conditions and remote surgery. Agriculture can benefit from real-time information on weather and soil conditions, which enables improved decisions on planting, irrigation, fertilisation and so on. Energy companies use sensors and analytics to monitor usage patterns and optimise energy supply. At one company we visited we observed an IoT-enabled automated warehouse, and similar technologies are being used in factory automation.

The control of lighting, heating and security through automation, voice and apps can be applied in domestic, industrial and city settings. Indeed, smart cities, such as Hangzhou in China, are looking at how the IoT can be used to comprehensively improve city living, including traffic flow, air quality and security. (For a relatively comprehensive list of IoT uses see Cambridge Consultants' report *Review of latest developments in the Internet of Things*, May 2017).

Overall the IoT could play a major role in sustainability, improving people's lives and enhancing productivity and economic growth. The use cases below illustrate some of these benefits, albeit our focus is on the management and accounting implications. Some of the examples discussed are at a pilot stage, and we also speculate on a few potential IoT uses. It should also be noted many IoT uses are interrelated: for example, improved asset tracking helps with cost management and supply chain management.

MORE ACCURATE AND AUTOMATED TRANSACTION PROCESSING

One of the most basic accounting benefits arising from the IoT is automated transaction processing, which brings with it improved data quality and reduced costs. Building on the long-established benefits of bar codes for recording sales and inventory, RFID tags improve the level of accuracy and degree of automation. One company we visited was selling RFID tags for car seatbelts so clients could register sales on a timely basis and prevent manipulation; previously sales had been recorded on paper forms or over the phone. RFID tags can also be used to record goods received. Combinations of various technologies including the IoT were also being used in China to automate the processing and approval of employee expenses, eg, taxis ordered through IoT-enabled ridesharing apps. Many uses discussed below also include transaction processing benefits.

ASSET TRACKING – REDUCE DOWNTIME, IMPROVE INFORMATION QUALITY AND SAVE AUDIT COSTS

IoT asset tracking is also relatively straightforward, and we saw many examples of this in China. Fixed assets, vehicles and inventory can all be confirmed to exist and their locations tracked automatically. The level of sophistication varies from industry to industry and company to company depending on the benefits obtainable and existing IT infrastructure.

Automated stock checking

At the basic end of the scale, we observed a company using RFID tags and hand-held scanners to confirm the existence of items of stock in a warehouse; this makes what might previously have been done through bar codes a little more efficient, as employees do not need to be in such close proximity. Moving beyond this, a Chinese accountant has set up a business with a system to monitor library stock. A mobile robotic 'tower' over two metres high automatically navigates the library and scans RFID tagged

books at a rate of over 24,000 per hour with a margin of error of 5%. This means inventory and book location can be checked and corrected more frequently rather than quarterly, as was the case with the old manual system.[18]

Asset location and catching thieves

For geographically dispersed assets the broadcast of GPS coordinates means that asset locations can also be monitored. If an asset which should be in a fixed location – such as a cooling system or battery – is moved, an immediate alert can be sent and remedial action taken. This reduces costly production downtime. If theft is involved, the chances of catching the thieves is increased.

Improved asset analysis and more efficient audits

One of the companies we visited was feeding IoT asset-tracking information into its enterprise resource planning (ERP) system and data warehouse. This enables finance to drill down into the detailed data. Where such systems are used independent visual (human or drone) asset and inventory audits are still required because tags can become detached and systems can be tampered with. However, these audits can be carried out more cost-effectively, as locations are more precise and issues will be more obvious.

RFID tags and cost benefit analysis

Among the Chinese experts we interviewed there were conflicting views on whether it made business sense to attach RFID tags to low-value items. This was partly because of differing views on the costs of the tags (which come with different levels of functionality and broadcast range) and the scale of cost savings available through reducing manual error, losses and theft. As costs come down and the technologies improve we expect to see continued growth in the use of the IoT for asset tracking.

IMPROVED ASSET UTILISATION THROUGH IMPROVED PROCESSES AND ASSET SHARING

Building on the use of the IoT for asset tracking, companies are also using the IoT to improve asset utilisation. This includes making the most of buildings, infrastructure, machines, vehicles and stock through improved usage data, process improvements and asset sharing.

For example, by tracking where people spend time, organisations can analyse the use of space in their buildings and reallocate it appropriately – perhaps by converting office space to meeting space, or vice versa, or sub-letting where the organisation has too much space.

In collaboration with Inspur, China Tower, a company which maintains and builds mobile telecoms towers on behalf of Chinese mobile operators, produces profit and loss accounts by tower. The IoT helps enable this by providing data on tower usage, energy consumption and downtime. The company is currently using this information to make greater use of underutilised towers. Initiatives include increasing the number of telecoms companies using each tower; attracting other users, such as those wanting to monitor environmental conditions to improve farming yields or reduce pollution; building new towers in locations which best enhance signal coverage; and relocating existing towers to better locations. Sensors also allow China Tower to better understand the use, performance and lifespan of backup batteries. This enables them to share and charge for backup power while minimising the risks to their own operations. Banks, which want to ensure cash machines are always operational, have been taking advantage of this service.

Bike sharing, facilitated by the IoT, has grown rapidly in China. There have been increasing problems though, such as bikes being damaged, piled up in inconvenient places or left in inaccessible locations. But with the accurate tracking provided by one of the companies we spoke to, these problems can be reduced through dynamic pricing, discounts and offers.

The management of commercial vehicles can also be improved through the IoT. In one case a Chinese logistics company is tracking vehicles very precisely to optimise routes taken, maximise loads in both directions and highlight when a driver might be taking a detour to carry on a private sideline business.

Asset utilisation – technical accounting benefits

The information the IoT provides on asset utilisation can be used to improve accounting accuracy. Slow-moving stock is more readily monitored and written down if appropriate. Tagged stock also enables finance to check whether specific item, average cost or last in, first out (LIFO) are the most appropriate inventory valuation methods. Asset utilisation data and a better understanding of asset lives can be used to improve depreciation, value-in-use and resale calculations and, based on these calculations, apply any necessary write-downs. At a higher level, IoT data on assets, costs and revenues (see below) can feed into goodwill assessments.

COST SAVINGS THROUGH ANALYSIS, PREVENTATIVE MAINTENANCE AND FIELD FORCE MANAGEMENT

Improvements in cost analysis

The IoT offers many opportunities to better understand and reduce costs. Again improvements in information quality provide the foundation by enabling accountants to better use the costing methodologies at their disposal. These include absorption costing, standard costing, activity based costing (ABC), throughput costing and target costing. Each has its pros and cons depending on circumstances and can be more or less difficult to implement. Data from the IoT can help to overcome some of the cons and ease implementation. For example, sensors can monitor machine run-times and labour activities to help with more accurate and timely absorption costing. Standard cost variances can be more accurately analysed between volume, mix and price variances. And the IoT provides opportunities to automate laborious ABC data collection.

The IoT also helps make previously hidden costs visible. Costs arising from mistakes and rework are a major issue and often not recorded in manual records. Sensors can track the genuine path of a product through a process and automatically record any deviations from the prescribed path, or 'happy path' as it is sometimes known. The costs associated with such deviations can be analysed and provide a stronger business case for addressing the underlying issues. Precise cost data also helps to determine priorities in achieving target costs.

Energy costs are another area where the IoT can help achieve reductions. We have mentioned the use of sensors to measure the actual energy usage of machines rather than the theoretical usage specified by the manufacturers. One company had analysed this sensor data and gathered suggestions from staff on when best to switch machines on and off. In addition the real-time data allows staff to quickly address faults which cause energy usage to exceed benchmarks. The IoT can also be used to monitor usage patterns and maximise the time available to charge batteries with cheaper, off-peak electricity while maintaining a continuous energy supply.

Preventative maintenance

Preventing expensive manufacturing line shutdowns and reducing maintenance costs is a key benefit of the IoT, and one of the companies we visited was focused on this opportunity. At the basic level, alarms can be sent when a machine or a machine component fails or is in danger of failing because of, say, overheating or excessive vibration. More sophisticated systems are designed to enable preventive maintenance. Data on predictor variables such as temperature, vibration, throughput, oil pressure and so on are collected and correlated with equipment failures. Models can then be built which predict when failures will occur, allowing the company to carry out maintenance in advance.

The companies we visited had seen good returns on their preventive maintenance models. However, producing accurate models can be challenging. Sufficient historic data might not be available, operating conditions may vary – mines operate under less controlled conditions than factories – and models need to be updated as machines age or are replaced. Moreover, care needs to be taken to avoid false positives resulting in unnecessary maintenance or maintenance carried out too soon. This is not easy as it may be necessary to allow machines to fail in order to gather the necessary data. Accountants should be well placed to analyse the efficacy of these models and weigh up the costs and benefits.

Field force management

Any business where people must visit locations to check whether work needs to be carried out can benefit from connected sensors which can remove the need for unnecessary visits. Mouse traps only need to be checked when they have been activated, fridges only checked when temperatures exceed a threshold, spaces only cleaned when they have been used and so on. This is yet another example where the IoT can be used to identify and reduce the hidden costs of wasted work.

There are no doubt many more opportunities for improved cost management resulting from the IoT, and accountants can take a lead in identifying such opportunities.

IMPROVED PRICING

Where prices are set on a cost-plus basis or by analysing marginal costs, better cost data generated by the IoT is clearly beneficial. For example, a logistics company we visited was carefully monitoring driving times, distances covered and product quantities on each delivery and was adjusting freight prices accordingly. The finance team was heavily involved in the decision-making process.

Real-time IoT data is also used for dynamic pricing based on supply and demand, which is clearly in evidence in IoT-enabled ride-sharing businesses.

QUALITY AND TRACEABILITY IMPROVEMENTS

The IoT is being used to improve product and service quality across a range of industries. In manufacturing, data from sensors and cameras feed models which can identify when a product does not conform to preset standards. The chemical composition of products can similarly be monitored.[19]

In addition, product provenance can be traced back though the supply chain using RFID tags and digital imaging (in some cases, supported by blockchain) to prevent counterfeiting or the substitution of lower-quality items.[20] For those dealing with perishable or fragile goods, sensors can monitor whether problems may have occurred in transit because of refrigeration failures or mishandling. The IoT also enables better tracking of expiry dates on perishable goods, with less risk of manipulation – date labels are easily tampered with or misread. Again, quality failures are often a hidden cost, which the IoT helps make visible.

QUANTIFIED EMPLOYEES – HEALTH AND SAFETY AND PERFORMANCE BENEFITS

A number of companies we visited had started using IoT technologies to monitor employee well-being and improve staff performance. At one Inspur client, workers working in inaccessible places with potentially hazardous conditions were equipped with sensors to monitor location, heart rate, blood pressure and blood oxygen levels together with environmental conditions, such as humidity and temperature. Where workers were seen congregating together this could be indicative of an accident, and raised heart rates or low oxygen levels could provide an early warning of illness. The initial models for alerts had been developed from generally available medical data, but they had been improved by using the data collected from workers to take into account actual working conditions.

This company had not, in general, looked at using the data to manage performance, partly because of the piece-rate incentive system in place. However, the improved data the IoT is providing on output by shift and by worker means feedback on production is now more accurate and immediate. Workers can see how much they have earned at the end of their shift rather than having to wait for the monthly accounts. This leads to increased performance because, as goal-setting studies have shown, timely feedback increases effort.

In addition, the company is introducing facial recognition checks to help ensure employees are not undertaking tasks they are not trained to carry out. It has also experimented with facial recognition to identify when an employee may be emotionally unfit for work, possibly endangering their own life or the lives of others. It is interesting to speculate whether this would ever be used on managers – the computer says, 'You're too angry to attend this important customer meeting!'

This kind of employee quantification is not restricted to China. It is, rather, a growing trend around the world. The extreme is found in sport, where every aspect of performance and training is monitored together with an increasing number of personal behaviours. When assessing and analysing players, Barcelona Football Club's innovation centre looks at in-game factors, such as distance run and sprints made, as well as general well-being factors, such as diet and sleep patterns.[21]

Of course, outside professional sport, some people choose to monitor their own wellness and fitness through trackers and sensors, with Chinese brands such as Xiaomi and Huawei taking on the likes of Fitbit and Garmin. However, the use of detailed employee data on health and behaviours by employers is not yet widespread.

When effective human performance depends on complex behaviours it is often easier to incentivise and manage people based on meeting objectives rather than try to analyse effort and behaviours. Targets, such as sales made, are easy to measure. However, output measures, even when improved by the IoT, can be a blunt instrument. Context and luck play their part in achieving sales, and short-term sales targets may be achieved at the expense of collaborating on longer-term improvements. The IoT offers opportunities to more effectively measure and manage behaviours. For example Humanyze, a spin out from the Massachusetts Institute of Technology, is using smart badges on employees which monitor location, body posture and voice characteristics (but not the content of what is said). From this data, the company claims to assess things like collaboration effectiveness, effort and stress levels and to link these to financial performance. Improvements can then be achieved through cultural change, training, team location, office layout and so on. Humanyze stresses the importance of privacy, and data is anonymised.[22]

Overall, finance could play a role in using data from the quantified employee to make better causal links between employee behaviours and financial performance.

MORE EFFECTIVE REVENUE ANALYSIS

IoT-enabled products allow sellers to provide additional services and monitor product usage. For example, smart TVs connected to the internet provide data on viewing habits and the usage of additional apps, such as games. In addition to creating a need for accountants to review whether revenue recognition rules are being met, there is also the opportunity to improve revenue analysis. In the past, manufacturers selling to wholesalers and retailers may have had little data on their ultimate customers. If they have access to the data on how their products are being used many of their information gaps can be filled.

Furthermore, with such IoT data, finance departments can more accurately match costs and R&D investment with the value consumers are placing on individual features of a product, rather than just on the product as a whole. Trends in product usage can also be identified more quickly and accurately. Overall, this helps organisations to make better product development decisions.

FORECASTING IMPROVEMENTS FROM BETTER ACTUALS AND GREATER DETAIL

Forecasts are often extrapolations of past performance. Clearly, the cases above and overall improvements in data quality resulting from the IoT will provide a better basis for such extrapolations. In particular, more timely and accurate data means forecasts can be built and responded to more quickly. It has also been argued building forecasts from frequent, lower-level data, which the IoT can provide, results in more accurate forecasts than first summarising the data.[23]

In addition, where the IoT enables better understanding of the causes of performance, finance can build and improve driver-based forecast models. This in turn means operational and financial forecasts can be more tightly integrated. It is worth noting that in China one of the reasons companies need to improve their forecasting is the revenue tax system. This taxes some products whether they are profitable or not, which increases the downside of continuing to produce unprofitable products.

IMPROVED RISK MANAGEMENT

Some of the use cases above clearly show how the IoT can help to reduce risk, eg, through responding more quickly to employees experiencing problems in hazardous environments or preventing production line shutdowns. IoT data is also being used to develop more sophisticated insurance options with premiums tailored to circumstances. For example, fleet managers can get reduced premiums if their drivers are shown to drive more carefully.

Generally, the IoT has limited implications for the liabilities side of the balance sheet. However, it could be used to better manage guarantees and warranties. Breaches of terms, such as failure to maintain oil levels in machines, can be monitored. And analytical models can be used to help organisations predict claim levels and prepare appropriately.

On a more macro-level, the IoT is helping organisations better understand and respond to the increase in extreme weather events associated with climate change. Models are improving and are more precise as a result of sensors sited at production facilities themselves rather than at weather centres. Organisations can use these models to decide where to improve flood defences or reinforce buildings against high winds.[24]

Accountants are often heavily involved with risk management in organisations, with the International Federation of Accountants calling for them to increase their role.[25] The IoT provides additional data that can help accountants identify, understand and manage risks in their organisations. On the other side of the equation, the IoT opens up additional risks, which we discuss in the section 'IoT challenges' (p24). It is worth noting accountants working in the insurance industry are likely to see a number of changes arising from the IoT, including new competitors, personalised premiums and usage-based insurance.

BRINGING IT ALL TOGETHER – BETTER DECISION-MAKING AND BUSINESS PERFORMANCE

All of the use cases above can improve accounting processes and management tasks. Bringing things together provides even greater opportunities. This is perhaps where accountants can bring the most value to IoT usage, as their position in the organisation gives them a good overview of a business and the challenges it faces.

Accountants who combine a range of IoT data with other data and financial information have a better chance of addressing the root causes of problems. For example, in retail a net decline in the profitability of a store may result from a range of factors. There may be a decline in customer satisfaction, which can be tracked back to a combination of increased queuing times and stock-outs originating from a shortage of raw materials. But this decline may be partly offset by an increase in satisfaction from giving customers the ability to verify that products are organic by using a combination of the IoT and blockchain.

Priorities for process improvements and automation can be set by analysing improved data on costs, asset utilisation, quality and risk. For example, companies we visited were using IoT data as part of their Lean/Six Sigma continuous improvement programmes. (Interestingly, one company we visited was working to five sigma because their cost benefit assessment suggested reducing variation any further would not be worthwhile.) Ultimately, through the IoT, digital twins, CCTV and augmented reality it should be feasible to fully visualise processes within and between organisations, look for efficiencies and deal with problems more quickly and effectively.

In addition, IoT data can be combined and analysed to help businesses make better strategic and investment decisions. And continual improvements can be made to the decision-making process if IoT data is used to inform rigorous post-decision reviews. Planning and budgeting processes can also be enhanced through improved data quality. Overall the IoT has the potential to transform management accounting and enhance the ability of finance departments to support their businesses.

How will business models adapt in the IoT ecosystem?

We have identified many ways in which the IoT can be used in accounting and management, while appreciating the broader implications. We have also argued a good way of understanding these broader implications is through the lens of ecosystems. The question then is how business models will adapt within the IoT ecosystem.

THE IOT, PLATFORM BUSINESSES, THE SHARING ECONOMY AND 'SERVICITISATION'

Many of the early leaders in making the most of the IoT have been termed 'platform businesses'. Uber and DiDi Chuxing, the leading car-sharing/taxi-hailing service in China, provide software platforms that match drivers and travellers by using the GPS-tracking functionality and internet connectivity of mobile phones. They do not own the cars and aim not to directly employ the drivers (although this practice has been successfully challenged in some countries, such as the UK). Similarly, many of those seeking to play a central role in the IoT aim to provide platforms which other members of the ecosystem can coalesce around. At the moment, this is a very competitive place, with cloud providers, software giants, telecoms companies and large industrial firms looking to provide a range of services and standards, either on their own or through more or less formal collaborations, including the Industrial Internet Consortium, which includes GE and Huawei as its founders; the Open Connectivity Foundation, which has Swedish home appliances firm Electrolux and Chinese consumer goods giant Haier as leading members; and Amazon's Greengrass IoT platform, designed to support edge devices, of which Chinese company Ayla Networks is a partner.

Some IoT platforms and applications provide a means of supporting the sharing economy. This plays to the strengths of accountants, who are aware of the need to 'sweat the assets' to produce higher profits. Manufacturing and operating fewer assets will also help save the planet. We discussed some sharing use cases under the heading 'Improved asset utilisation through improved processes and asset sharing' (p13).

'Servicitisation' is another important business model supported by the IoT. Perhaps the best-known example is the move by jet engine manufacturers to provide power by the hour rather than selling or leasing engines. The IoT facilitates such a business model through improved usage statistics, better demand forecasting and preventative maintenance, leading to competitive pricing and effective risk sharing between supplier and customer. Additionally, as we have seen, services can be added to products through the IoT both to add revenue and better understand how a product is used.

THE IOT AND 'BRICKS-AND-MORTAR' BUSINESSES

The IoT is also providing a means for bricks-and-mortar stores to catch up with more profitable software and e-commerce companies. One of the companies we spoke to was enabling physical stores to compete with e-commerce giants through the idea of 'on-line to off-line' (O2O). The approach is for stores to set aside an area as a small warehouse for the most in-demand products, with inventory levels monitored in real time through RFID tags. A logistics company then provides an app through which customers can order products from the store and get guaranteed local delivery within one hour. Delivery is provided by self-employed scooter and bicycle riders, who are tracked, monitored and assessed through their mobile phones and customer feedback.

MANUFACTURERS ADD DATA SERVICES TO THEIR PORTFOLIOS

The manufacturing companies we spoke to were all aiming to develop data and analytics services. Indeed, in one company the data science and finance teams had worked together to build a highly accurate optical character recognition (OCR) system for digitising and recording travel documents, tickets and invoices using machine learning. They are now selling the service through an application programming interface (API) for the equivalent of US$0.01 per transaction.

The move to providing data services is driven by the knowledge that services have higher margins than manufacturing. For example, chip and SIM card manufacturers are gathering data from machines and vehicles, including on driver behaviour, and are providing analysis back to the manufacturers. This data is being provided to insurance companies so that they can better understand individual risks and set premiums appropriately. Greater success is currently being seen in Europe compared to China because the insurance companies are more advanced. This is another indication of how ecosystems are important in determining which products will take off and where. Again, finance departments will need to be aware of ecosystem dynamics when contributing to strategy, investment decisions and the allocation of resources across products and services.

McKinsey and Accenture have both suggested the growth in the IoT will lead to the development of data marketplaces.[26] The idea is that the IoT is producing many huge data sets which are currently underutilised. Companies producing such data find it difficult to monetise, and those wishing to combine data sets to produce new insights find data difficult to access. A marketplace would help both parties. However, as far as we can tell, well-developed IoT data marketplaces are currently few and far between.

THE IOT ECOSYSTEM AND COMPANY STRUCTURES

Companies will need to consider how the IoT ecosystem impacts on their structures. In China, Haier, the world's largest white goods manufacturer, has publicly embraced the idea of ecosystems with a strong focus on the IoT.[27] It has actively sought to move away from having large business divisions to nurturing micro-entrepreneurs supported by innovation, service and finance platforms. Indeed, the finance department has been actively involved in these developments, and a number of its services, such as accounts payable, are partly delivered through accountant micro-entrepreneurs. Supported by automation technologies, such as robotic process automation and OCR, this organisational structure has led to cost reductions and significant improvements in the provision of management information, including the measurement of shared value within its ecosystem. It is also not surprising that Haier's highly innovative finance function is also ahead of others in looking at the ways in which the IoT can support its work.

TAKING ACCOUNT OF ECOSYSTEMS IN THE FINANCE DEPARTMENT

CFOs and accounting leaders will need to influence how their organisations operate within their ecosystems based on careful consideration of the organisation's strategy and competitive position. An awareness of what can be achieved through the IoT will be essential to such considerations. Finance leaders will also need to understand the complex interrelationships within the ecosystem when developing management control systems. For example, allocating revenues and costs between partners who provide different services and have different long-term objectives will require careful negotiation. Forecasting, financial analysis, budgeting and many other financial disciplines all take on different characteristics if an organisation needs to put a value on its ecosystem or moves from selling products to providing services or a platform.

The internet of things and the knowledge, skills and attitudes of accountants

What knowledge, skills and attitudes accountants will need to develop as the IoT expands will depend on a range of factors. Accountants have diverse roles and work at different levels of seniority, and so they will focus on different aspects of the IoT ecosystem. The degree to which an organisation can employ specialists, such as data scientists, will influence how much an accountant will need to know about the IoT and the degree to which they will use IoT data directly. IoT technology and associated data tools are developing quickly, meaning knowledge and skill requirements will need to be regularly updated. There will also be different requirements for different stages of an IoT programme – opportunity identification, business case development, implementation and use.

TO WHAT DEGREE WILL ACCOUNTANTS GET INVOLVED WITH THE IOT?

Many of the non-finance department interviewees were sceptical about accountants being heavily involved with the IoT. The main opportunities were seen in operations, with line managers driving adoption and being the main users. The finance department might help with business case financials, and the CFO was seen as influential in go/no-go decisions, but they were not generally expected to be proactive. Data scientists were the main players in making use of IoT data and providing services to the rest of the organisation. Accountant involvement in advanced analytics was predicted to be limited, in part because data science skills were seen to be difficult to acquire.

However, some non-finance department interviewees saw a wider role for accountants, which was supported by finance interviewees. Given the potential impact of the IoT discussed above, we believe accountants will need to embrace the IoT and work out how best to get involved and make use of it. Below we discuss some ideas on how accountants can develop the knowledge, skills and attitudes necessary to do so.

DEVELOP GREATER UNDERSTANDING OF THE POTENTIAL OF THE IOT

The first step is for accountants to understand the nature of the IoT and the possibilities it generates. Reading and talking to experts inside and outside one's organisation is a good place to start. This may lead to ideas on how IoT systems already in use could be used in finance or the initiation of new projects. Finance departments are in a good place to see priority areas for revenue generation, cost savings and better asset utilisation. In addition, process problems often manifest in finance; for example, errors in inventory, work-in-progress or asset recording can be indicative of broader issues. Accountants should also understand what information improvements would help run businesses more effectively. As we have seen, the IoT can help in all these areas.

There are also intangible benefits. If the IoT develops as rapidly as expected, then early investment, while not necessarily producing a significant return, will enable an organisation to learn and react rapidly as the IoT matures. Therefore, it is worth considering real options approaches to IoT investment decision-making. Of course, accountants have to be aware of the costs, limitations and risks of the IoT in order to develop well-thought-through business cases.

GET INVOLVED WITH IOT PROGRAMMES FROM THE OUTSET

Early involvement of accountants in IoT programmes will increase the chances of broader management benefits, such as improved management information, being considered, as well as direct operational benefits. Achieving this involvement, in the face of possible resistance, will be challenging. Therefore, accountants will need to be proactive, courageous, confident, willing to take risks and good at building relationships. They will also need to find the time to get involved, and demonstrate they can add value to IoT programmes. In particular, they will need to build trust that they are there to be supportive, and only challenge ideas out of a desire to act in the best interests of the company rather than to unnecessarily

block progress. Trust will also be important for finance departments looking to get access to IoT data – managers may feel they are being checked up on, and data concerning employee performance is sensitive.

DEVELOP ANALYTICAL AND CODING SKILLS

The depth and breadth of knowledge that accountants need to develop around the use of IoT data and analytics is debatable. Some accountants build successful careers by working through the detail, while others are equally successful through focusing on the big picture. Certain interviewees were of the view that a basic knowledge was sufficient and accountants only need to be in a position to ask the right questions and understand the principles.

In many cases, there are simple uses of IoT data which should not require accountants to develop any additional knowledge. As we have seen, uses such as tracking assets and optimising asset usage can be straightforward. For more complex uses accountants could choose to rely on the work and outputs of other experts such as technologists and data scientists.

However, others felt genuine engagement with the IoT was not possible without going deeper and learning more about data science, maths, statistics, coding, algorithms, model development, machine learning and artificial intelligence.[28] One CFO we spoke to had just started to learn to code in Python, a programming language often used by data scientists. His view was he needed to do this in order to ensure he would remain qualified to be a CFO. He felt that, even if he did not use coding skills directly, he would need such knowledge to work with other areas and to manage more junior accountants, who he believed would start to code. Interestingly, he had not told his boss as he was not convinced the CEO would see this as a priority. Based on this he felt finance staff in general would need to learn such skills in their own time.

The risk with learning a particular coding language or approach is that it might become obsolete as better, more user-friendly tools become available. Building complex algorithms, such as neural networks, from the ground up used to be arduous and time-consuming. Now, freely available packages provide a starting point and take out a lot of this effort. However, coding does provide many transferable skills, including careful problem definition, increased understanding of algorithmic black boxes, logical thinking and attention to detail. Working with data using the vast array of analytical tools available is a useful way of developing practical knowledge and skills, which may not be possible by just understanding the concepts.

Another finance interviewee was also looking at how she and her team could develop further data science skills. Motivated in part by the reasons discussed above, she also wanted to reduce her reliance on separate IT and business intelligence departments. This reflects an age-old problem for finance departments in getting their needs prioritised when there are many demands on IT. This is part of the reason for the continued ubiquity of spreadsheets – we generally prefer to be in control rather than dependent on others.

DATA LITERACY IS AS IMPORTANT AS FINANCIAL LITERACY

There are parallels to be drawn between accounting and data science when it comes to knowledge, skills and attitudes. The importance of accounting to organisations means that we expect general managers to be financially literate. This will also become the case for data literacy if decision-making becomes more data driven. We are already seeing organisations, including US accommodation platform Airbnb and UK energy company Centrica, running data science courses for non-data scientists in the same way that organisations have long run courses on finance for non-financial managers. Questions

around whether you can really understand a set of accounts without having had experience of preparing accounts are mirrored by questions around whether you can really understand analytics outputs without experience of undertaking some analytics projects. We also know some accountants get frustrated when general managers pay insufficient attention to accounting information and its underlying messages and assumptions – we hope accountants will not take a similar attitude when presented with advanced analytics from the IoT.

THE VALUE OF ACCOUNTANTS' EXISTING SKILLS

Accountants already have a number of skills invaluable to the use of IoT data. They are used to identifying data sources, cleaning them up and combining them – 'data wrangling' in data science terminology. They are numerate and can make the connection between IoT data and financial reports. One role for accountants may be in translating and communicating IoT analysis to business managers and helping them get the most out of it. At a French utilities company, it was the finance business partner who took the streaming temperature data from water tanks used in cooling towers and turned it into a dashboard which managers could use to pre-empt the risk of contamination by the bacteria responsible for Legionnaires' disease.

Accountants should also be well versed in expected value calculations,[29] which can be developed to assess the value in collecting additional data and to evaluate models. Indeed, accountants can probably pass on useful knowledge to data scientists. Data control, reconciliations, standardisation, consolidation, summarisation and presentation should all be second nature to accountants. They can also advise on audit trails, which may be important in explaining and justifying decisions. How to deal with cut-off issues is particularly important when dealing with time series data, again something accountants are used to dealing with.

COLLABORATE TO LEARN

The best ways to learn more are to get involved with IoT projects and collaborate with data scientists. Indeed, a few finance teams have recruited data scientists not only to help with day-to-day work but also to facilitate knowledge transfer.[30] For those who are keen to learn more, but who do not have access to IoT projects at work, it is possible to experiment at home: there are many cheap computer boards, sensors, free software packages and forums to support IoT hobbyists.

The data produced by the IoT provides a significant opportunity for accountants to use their existing information skills in supporting their organisations. Through being proactive and creative and by learning new analytical skills, they can play a lead in IoT developments and add further business value. Will accountants have sufficient motivation to do so and will organisations be supportive of their efforts? Only time will tell.

IoT challenges

THE IOT ADDS TO CYBER SECURITY RISKS

The two biggest challenges facing the IoT ecosystem are security and privacy, which we discuss below. We also discuss why insufficient attention is being paid to IoT cyber security, and we explore the Chinese context and the role of accountants in IoT cyber security.

IoT and security

The IoT opens up risks of hacking attacks on vital infrastructure which could lead to significant harm. Health, energy and transport infrastructure have always been vulnerable to attack, but now malevolent actors no longer need to be physically present and the potential scope and scale of such attacks is much greater. While there is little visible evidence of successful, large-scale infrastructure attacks (apart from on internet infrastructure), regulators, security companies and researchers have pointed out vulnerabilities that could be exploited.[31] The BBC has reported on a survey by the Ponemon Institute of security professionals who work protecting critical infrastructure in the utilities, health, transport and energy sectors; 90% of the respondents acknowledged they had been hit by at least one successful attack.[32] The most well-known IoT-based attack was the 2016 Dyn cyberattack. This used the Mirai botnet – which takes advantage of connected devices, such as cameras – to launch a denial-of-service attack on the servers of Dyn, which controls much of the internet's domain name system. This resulted in significant disruption to sites such as Twitter and Netflix.

IoT and privacy

The IoT also extends the range of personal data being collected – data which can be linked with other personal data available on social media. What we watch on TV, our health data, whether we are at home and much more can all be acted upon. Connected CCTV cameras used in home security systems have been easily accessed by those without authorisation, mainly owing to the use of default or weak passwords. Those with access to such data, gained legally or illegally, can abuse it, for example by committing identity theft or burglary, exposing private matters (such as sexuality or mental health issues), conducting inappropriate surveillance and restricting people's freedom.

It is also worth noting that corporate IoT data which improves organisational performance would also be of value to competitors. The IoT extends the risks of corporate espionage – for example, with the aim of understanding a competitor's cost structures, production levels or how its products are being used.

Insufficient attention being paid to IoT cyber security

Commentators argue insufficient attention is being paid to IoT cyber security issues.[33] There are a number of contributing factors. Firstly, it is sometimes difficult to know which products are connected to the internet and what data is being collected by whom. Investing in cyber security protection on low-margin IoT devices, such as TVs, white goods and sensors, may not be commercially viable. Updating dispersed and diverse IoT devices with security fixes is not easy and is, in some cases, impossible. Because the IoT is still quite new, relatively little time has been spent on addressing these issues.

Blockchain has been touted as one of the solutions to IoT security and privacy issues. It can certainly help with areas such as verifying the identity of an IoT device and the secure transmission of data. However, there are limitations when applying the technology to devices with limited processing power and memory. A development known as the Tangle, an alternative approach to distributed ledgers,[34] may help overcome some of these issues.

The IoT and cyber security in China

The Chinese companies we spoke to were well aware of the above issues. They realise that an actual or perceived security or privacy breach will damage their business and reputation, reducing their licence to operate. At present, regulation in China around data protection is relatively light and more in the form of guidelines than legal frameworks, although these guidelines have been used in law enforcement actions.[35]

China also has a different attitude to what constitutes acceptable use of data from that of some other countries. The Economist Intelligence Unit states, 'China's social credit plan for 2014-20 calls on government bodies to centralise the data they hold on companies and individuals … The social credit plan does not refer to a scoring system for citizens' behaviour. However, this has since been experimented with under pilot schemes in a small number of cities.'[36] The nature of the pilots varies, and it is not always clear what types of data are being used. How things will play out at the national level is also unclear.[37] However, where people are placed on a blacklist this can impact an individual's ability to travel, access public services and start a business.[38]

In addition, according to the *Financial Times*, 'A number of Chinese laws state that Chinese individuals and organisations must, if asked, cooperate with intelligence work.'[39] It is unclear whether this applies to the operations of Chinese entities outside of China. Organisations will need to carefully consider the implications of international and local legal systems on government access to the data they hold.

Some public debate on privacy issues is taking place in China. For example, in November 2019, China's *Global Times* reported on DiDi's online survey about audio and video recording of taxi drivers and their passengers. At the time, a majority were in favour for safety reasons, but a significant minority thought it an invasion of privacy.[40]

Accountants and IoT cyber security

In their audit and risk management roles, accountants need to be aware of the cyber security risks inherent in the IoT and how they can be managed. Accountants will be part of setting up the management systems and structures needed to manage the risks. In particular, CFOs will need to ensure cyber security risks associated with the IoT are considered at board level. And lastly, IoT investment decisions need to factor in the costs of addressing security and privacy risks. (For further information on cyber security, see icaew.com/cyber)

IoT security and privacy failures can do more than damage company reputations and profitability: they present significant risks to economies, political systems and people's lives. Dealing with these risks must be a high priority. And the accounting profession, drawing on its ethical foundations and public interest mandate, must play a leading role.

ESTABLISHING DATA OWNERSHIP

With data seen as increasingly valuable to businesses, the ownership of and access to IoT data needs careful attention. The position can be complex. For example, with an IoT-enabled machine, data ownership could reside with the manufacturer of the machine itself, the makers of the sensors attached to the machine, the owners of the machine, those providing connectivity, the software providers or

the providers of cloud storage. Any of these may want to provide further access to third parties, such as analytics companies or data marketplaces. In addition, regulators and governments may have legal rights to access certain types of data.

Our interviewees were well aware of the need to set up contracts setting out data ownership and access rights. Companies specialising in data analytics were often bound by clauses not to disclose data to third parties and only to use data for specific purposes.

Accountants involved in commercial negotiations around the use of data and the valuation of associated rights will need to be aware of the issues and work closely with lawyers and other specialists.

THE IMPACT OF CONSTANT OBSERVATION AND THE RISKS OF MICROMANAGEMENT

Observation, or even the possibility of being observed, changes behaviours. We all probably behave differently when sitting alongside our boss compared with when they are elsewhere. The impact of constant observation and the observation of previously hidden performance-related variables, such as heart rates, is not yet clear. Will behaviours change on a long-term basis or will people become immune to the effects and revert to their old ways? Quite rightly, some employees will see constant monitoring as an invasion of privacy and will become demotivated or leave. Employers seem wary. For example, one of our interviewees said he was happy to facilitate employee performance through monitoring working conditions such as high CO_2 levels which reduce productivity, and food hygiene in the staff canteen to prevent illness. However, 'if someone wants to get drunk the night before work, that's their problem.' Monitoring by the state, police and regulators will also affect behaviours.

How this all plays out will depend on how much we trust those gathering the data and on the relative power of the observer and the observed. Also important will be the levels of transparency and communication, how the data is used in providing feedback, the regulations put in place and the nature of incentives and punishments.

The IoT also brings risks of micromanagement, although this was not considered to be a serious issue by our interviewees: 'This is a must. Top management must see this [detailed] data; only by them seeing it can they optimise the results.' The concern is that the visibility of operations the IoT enables may mean the focus on operational decisions comes at the cost of not thinking about strategy, innovation, marketing, investor relations and so on. If such micromanagement becomes common place, employees may become demotivated because of constant interference. Even with the benefits the IoT brings, centralised decision-making can still be slower and reduce an organisation's agility. Striking the right balance between empowerment and control is not a new issue, but the IoT brings it to the fore.

ESTABLISHING VIABLE BUSINESS CASES – ESPECIALLY IN CONSUMER PRODUCTS

As our examples show, we saw a number of successful IoT implementations. However, there are still many organisation that do not see a viable business case for utilising the IoT or have found that it does not make sense to scale up pilot projects. The World Economic Forum (WEF) and McKinsey refer to 'piloting purgatory', where companies have experimented with IoT and advanced manufacturing technologies but have not yet taken them further. Three of the top four reasons for this were the high cost of scaling, difficulties in justifying business cases without a short-term impact and pilots demonstrating unclear business value.[41] The WEF and McKinsey report almost frames this as businesses making excuses; but maybe businesses have found promised benefits have no chance of being delivered at this stage of the IoT's development. Alternative solutions may also be available. To prevent shelf-outs, US DIY chain Home Depot uses a machine-learning algorithm based on non-IoT data such as product type, pack size and shelf size rather than cameras or RFID tags, although they are also

investigating these technologies.[42] The marginal benefit of improved data quality from the IoT can be small in already efficient organisations; for example, some organisations achieved very low inventory levels before the advent of the IoT.

Although they have been available for many years, connected consumer devices have struggled to reach significant market penetration. Electrolux was ahead of its time when, in 1999, it showcased its Screenfridge, which allowed users to access email and scan barcodes to create a shopping list. Yet developments in connected fridges with sensors, which can re-order milk before you run out, still do not seem to be taking off. Some have ridiculed IoT consumer products such as connected toothbrushes and baby bottles. However, the rapid growth in voice-activated home assistants, such as Amazon's Alexa, Google Home and equivalents from Alibaba and Xiaomi, connected to home heating, lighting, entertainment and security, is starting to change attitudes. Cultural differences play their part. Electrolux had more success with its connected products in Scandinavia; and, as we have seen, China is embracing the IoT for a number of reasons.

The viability of IoT business cases in both business and consumer markets will improve over time. Products will get better and costs should come down through manufacturing improvements and economies of scale. These forces may be partially offset if monopolies emerge or prices have to be increased to adequately address cyber security issues. Replacement cycles will also play a significant role. As one interviewee pointed out, manufacturers of industrial machines will increasingly struggle to sell their products unless they have integrated sensors and connectivity. We will also get better at understanding the strengths and weaknesses of the IoT, and we will learn where best to apply IoT solutions and how best to implement them.

CONVERTING TACIT KNOWLEDGE INTO EXPLICIT KNOWLEDGE

Although the IoT generates significant improvements in the amount and quality of data available to inform decision-making, there are still challenges around converting tacit knowledge into explicit knowledge. In one company the interviewee talked about how they had still not reached the stage of being able to replicate the ability of experienced operators to place their hands on a machine, listen to it and then correctly assess whether the machine needed maintenance. From this difficulty, we could also surmise that combining accounting data and IoT data will not soon be able to replicate the experienced accountant's ability to spot business issues through reviewing a set of accounts. Reaching a position where analytics can combine disparate sources of data to mimic human intuition will require creativity and close collaboration between subject matter experts and data scientists. This plays into broader questions around developments in AI and what will remain uniquely human in the future.

STANDARDS AND INTEROPERABILITY ISSUES REMAIN A PROBLEM

The wide diversity of actuators, sensors, connectivity approaches, platforms, operating systems, application software, data formats and communication protocols results in a number of challenges. Selecting the right products is difficult, and integrating devices from different manufacturers into an effective system takes significant effort. Gartner research suggests 'half the cost of implementing IoT solutions will be spent integrating various IoT components with each other and back-end systems.'[43]

We have mentioned some of the initiatives to address these issues through unified standards, but much remains to be done. There is also the challenge of finding the right balance between the efficiency that standards facilitate and the value of competing standards for innovation and monopoly prevention. We can see a parallel when we look at the costs and benefits of different accounting standards, such as US GAAP and IFRS. Hopefully the IoT ecosystem will develop in such a way that a suitable equilibrium is achieved.

BUILDING THE NECESSARY INFRASTRUCTURE

The expansion of the IoT requires further developments in infrastructure. Geographic coverage is limited by connectivity costs – mobile or satellite connectivity can be too expensive. Even where connectivity exists, the reliability of connections and data speeds (upload and download, bandwidth and latency) is a barrier to rolling out technologies such as autonomous vehicles. This issue can be exacerbated by the lack of power supplies in remote areas, and using batteries or local generators is expensive. Cloud and network infrastructure also have to be upgraded to deal with huge volumes of streaming data, which also means data storage costs soon mount up. Organisations have to prioritise what data to keep and do not always get this right. One company we visited regretted not keeping data which it would now find useful for predictive maintenance models.

These issues are all being addressed as new technologies are rolled out and innovation continues. The most well-publicised technology is 5G mobile connectivity, where China leads the way both in terms of equipment manufacture and pilot rollouts. 5G comes into its own for the IoT in areas such as robotics, autonomous vehicles, drones and health monitoring from a distance. This is because not only does 5G improve reliability and data download speeds, it also significantly increases upload speeds to attain the same level. Therefore, two-way communication between devices and between devices and the cloud is greatly improved. However, roll-out will take time – Erickson predicts that by 2024 potentially 65% of the global population will have access to 5G.[44]

Other areas are also advancing. Batteries are becoming cheaper and more energy efficient, and they need charging less frequently. Sensors are being designed to reduce energy consumption. Low-power wide-area network technologies are also moving ahead. The aim according to the LoRa Alliance™ is to achieve 'fit and forget', where once sensors are fitted no battery charging, replacement or maintenance is required.

DOUBTS OVER SENSOR ACCURACY

One of our interviewees raised concerns about the variability in sensor readings, and further investigation suggests this is an issue. According to Yodit Stanton, CEO of OpenSensors.io, there are no standard benchmarks for measuring sensor accuracy and there are concerns some companies are not carrying out rigorous testing.[45] Even if laboratory tests show sensors are accurate, this may not be the case when sensors are used in the field, where operating conditions can vary widely. Care is also required in considering the elevation of a sensor as well as its map coordinates because this will impact readings on things like air quality and temperature.

DATA SKILLS SHORTAGES – SPECIFIC IOT ISSUES

Highly qualified data scientists and data engineers seem to be in short supply globally and in China.[46] The problem is exacerbated when it comes to IoT data because even those with good systems and data skills may require some additional training. Data engineers need to learn how to design and optimise systems, networks and databases to deal with huge volumes of streaming data. In addition, building models based on this data requires a good understanding of time series analytical techniques which are not always covered in data science courses or books. When IoT devices are deployed outside, in mines or on moving objects, models have to take into account variability in the environment. Once the model has been built most of the ongoing stream of data may be useless (apart from when a model needs to be recalibrated) as it is anomalies the model will be looking for. Therefore, data engineers will need to compare the costs of transmitting and dealing with the useless data in the cloud versus spending on edge computing to deal with the issue at source.

Expanding the boundaries of accounting with data from the internet of things

Accounting has remained a valuable business tool both because of the elegance and efficacy of double-entry bookkeeping and thanks to the profession's ability to integrate new ideas and new technologies. The pace of integration has varied though. Finance departments were among the leaders in using mainframe computers to process transactions in the 1960s and using spreadsheets for analysis in the 1980s. Conversely, in the 1930s, many accountants resisted using discounted cash flow and net present value calculations for investment decisions. Similarly, some professional accounting bodies initially took the view internal cost accounting was not something they wanted to support and did not provide guidance, training or qualifications. In this light, many in the accounting profession are concerned we are getting left behind when it comes to making the most of big data and analytics. Would including data from the IoT within the boundaries of accounting help prevent this?

One could argue that the ambiguities around the definition of accounting are what has allowed it to thrive. Accounting has gone beyond the entries and totals in ledger accounts. Annual reports and management accounting packs contain a wealth of information on KPIs, risks, customer satisfaction and so on. The term accounting is linked to 'giving an account of something' and 'accountability', which further enriches its meaning. Management accounting scholars sometimes prefer to use the term 'calculative practices' rather than accounting to avoid focusing too narrowly. With digitalisation, the conversion of pictures and sounds into ones and zeroes, the option to work on most business problems through calculation increases. Even the analysis of language is advancing through calculation – advances in natural language processing and generation (the ability of software to translate, categorise, summarise and write) are in part being driven by converting words to vectors (in this case 'vector' means a series of numbers). Broadening the scope of accounting to embrace new data generated by the IoT and other digital technologies does not seem to be an unreasonable step.

Big data, including IoT data, could reduce the value of financial reports and analysis in decision-making and management processes. If we can use real-time CCTV, digital twins and visualisations to better 'see' what is going on, how resources are being used and how people are performing, will senior managers place less reliance on accounting? Many managers would prefer not to have to spend time reading and considering accounting reports, especially if they are not timely. And accountants should be willing to let go of accounting tools and techniques that are no longer required if the IoT provides better solutions they can use. At the moment though, a significant decline in the value of financial and management accounting seems far-fetched; as discussed above, accounting information still has the unique capacity to accurately combine, summarise and compare data across time and all aspects of a business.

We hope our discussion of IoT uses in accounting helps open up further possibilities for improving and expanding the usefulness of accounting. There are many opportunities still to explore, such as using accounting and the IoT to help deliver the United Nation's Sustainable Development Goals. For example, through better accounting for the human and financial benefits of clean water and sanitation (goal six) we can help drive improvements.

On occasion, increases in quantity can lead to qualitative changes – for example, big data is necessary to make artificial intelligence work. Could accountants use of the vast volumes of IoT data to transform their work? If risks to the value of accounting exist, they can at least be minimised by working to combine financial information and IoT data to further develop accounting and improve decision-making and innovation.

We believe accountants who use their creativity and imagination, while drawing on their existing skills and developing new ones, can play a leading role in making the most of the IoT.

Invitation for engagement

Our earlier report, *Big data in Chinese businesses*, invited interested parties to get in touch with the Big Data and Accounting Research Centre partners (SNAI, Inspur and ICAEW) to build further understanding around the opportunities and challenges in big data. Similarly, we would be delighted to engage with those working on the IoT, to further explore the following topics:

- Additional examples of using the IoT to improve management and accounting processes, considering what works and what does not;
- The ways in which finance departments are collaborating on IoT programmes;
- How the IoT may be changing the balance between what is managed locally and what is managed at a distance;
- The ways in which the IoT ecosystem is developing;
- The knowledge and skills that accountants need to develop to make the most of the IoT; and,
- How the challenges associated with the IoT, such as security and privacy, are being addressed.

ICAEW and SNAI continue to review how they can support employers, students and members with the opportunities and challenges presented by new technologies. We regularly review our syllabuses, provide a range of resources and have developed several training courses. We also hope that this report will encourage organisations and individuals to look at what they need to do to thrive in the digital age.

We will continue to conduct research into the use of big data so we can support the development of the profession and help accountants deliver greater value to businesses, economies and societies.

To find out more, please contact bam@icaew.com

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Further reading and resources

For more information about the IoT see the following:

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'The Next Economic Growth Engine: Scaling Fourth Industrial Revolution Technologies in Production', World Economic Forum/McKinsey, 2018.

'How greater China is set to lead the global industrial IoT Market', GSMA, July 2018.

For more ICAEW resources relevant to the themes in this report, see the following:

'Providing leadership in a digital world', ICAEW, 2015.

'Big data and analytics: the impact on the accountancy profession', ICAEW, 2019.

'New technologies, ethics and accountability', ICAEW, 2019.

Cyber security hub: icaew.com/cyber

Finance in a digital world: icaew.com/fdw

End notes

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